Building Decarbonization (Electrification) for Hydronic Systems

Mick Schwedler, PE, FASHRAE, LEED AP BD+C
ASHRAE Distinguished Lecturer 2023-2025
ASHRAE Presidential Member 2021-2022
Trane Applications Engineer

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Course Description

Many people have been educated on what decarbonization is, as well is its goals. This presentation delves into how hydronic systems using heat recovery chillers, heat pumps and chiller/heaters can be designed, piped, optimized and controlled in order to provide heat efficiently. Also covered are the impact of hot water and outdoor air temperatures, methods to simplify system design and operation, the importance of ensuring building operators and facility managers can operate the systems as intended. The goal is to reduce environmental emissions and make the system as simple as possible, but not simpler.

Recommended audience: Facility managers, sustainability coordinators, chiller plant operators, engineers, contractors, controls providers, educators, students.

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Building Decarbonization (Electrification) for Hydronic Systems

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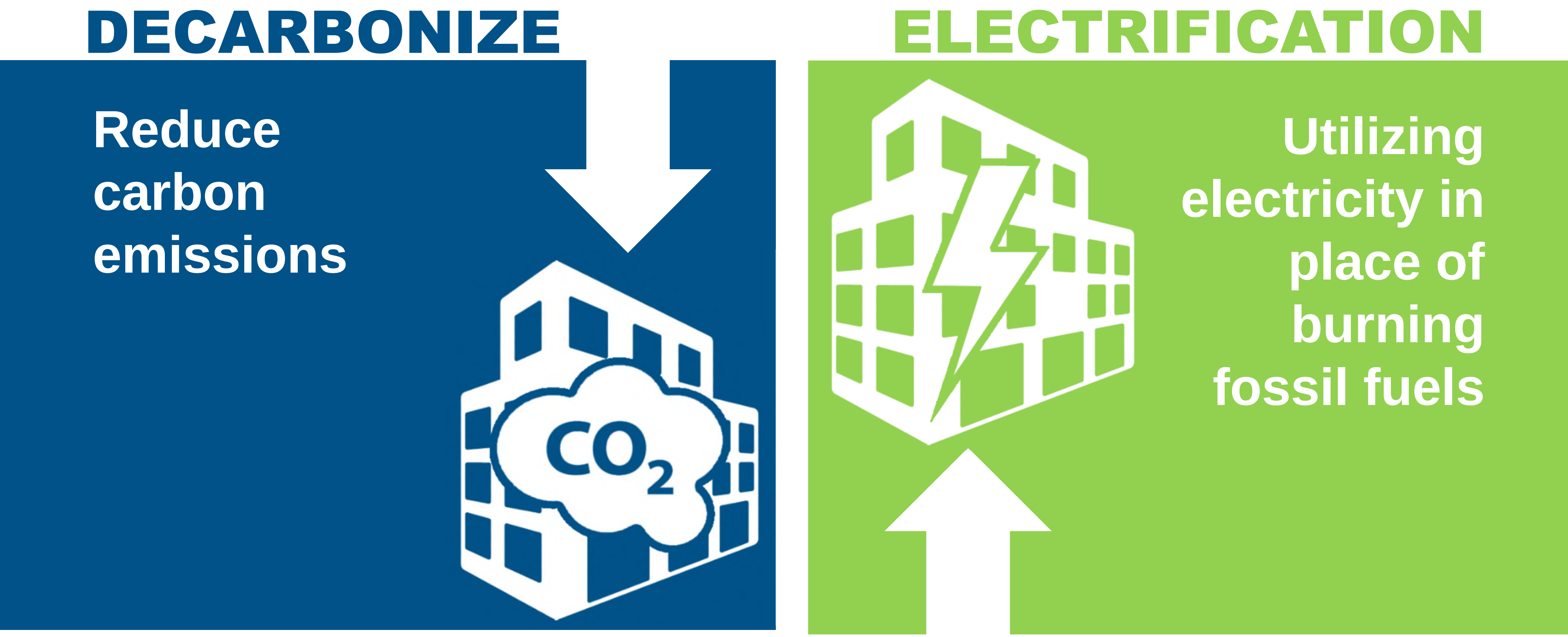
Learning Objectives

1. Comprehend the difference between decarbonization and electrification
2. Understand the possible direct impact of refrigerant choice
3. Recognize energy and capacity impacts of:
   - Heating water temperature
   - Heat source temperature
4. Appreciate differences from traditional chilled water system design

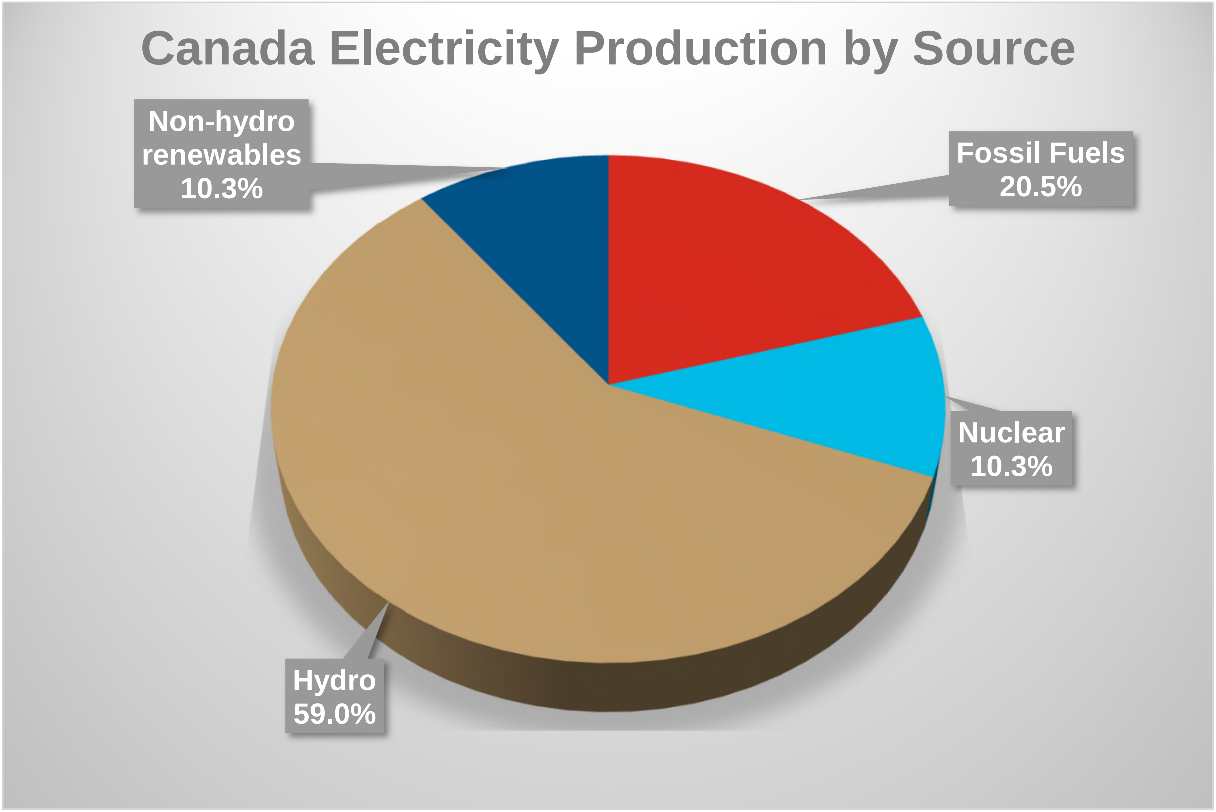
<u>Not</u> on the Agenda

- Embodied carbon
- Financial analysis
- Today’s goal is education

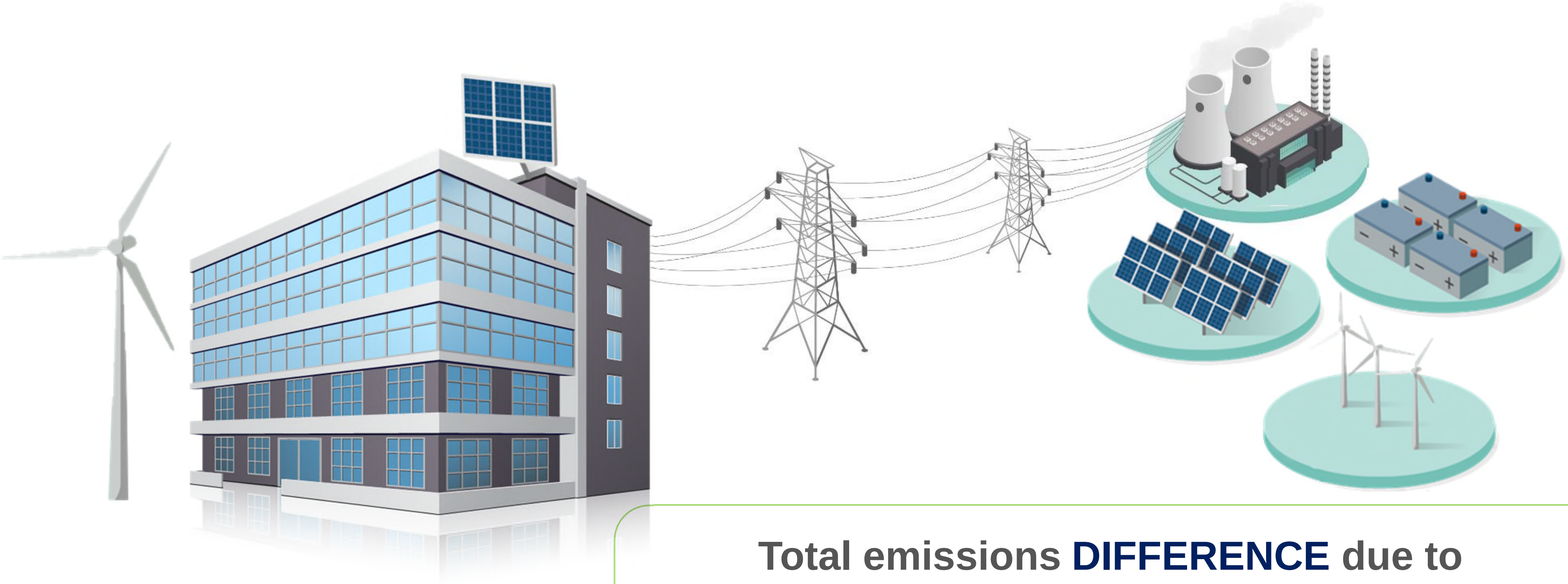


If the goal is to reduce total operational carbon emissions, building plus grid emissions <u>must</u> be considered

Canada (2019)
Changes by Province



Electric Grid Migration to Renewable / Carbon Free



Total emissions **DIFFERENCE** due to electrification is dependent on the mix of grid production and grid emissions

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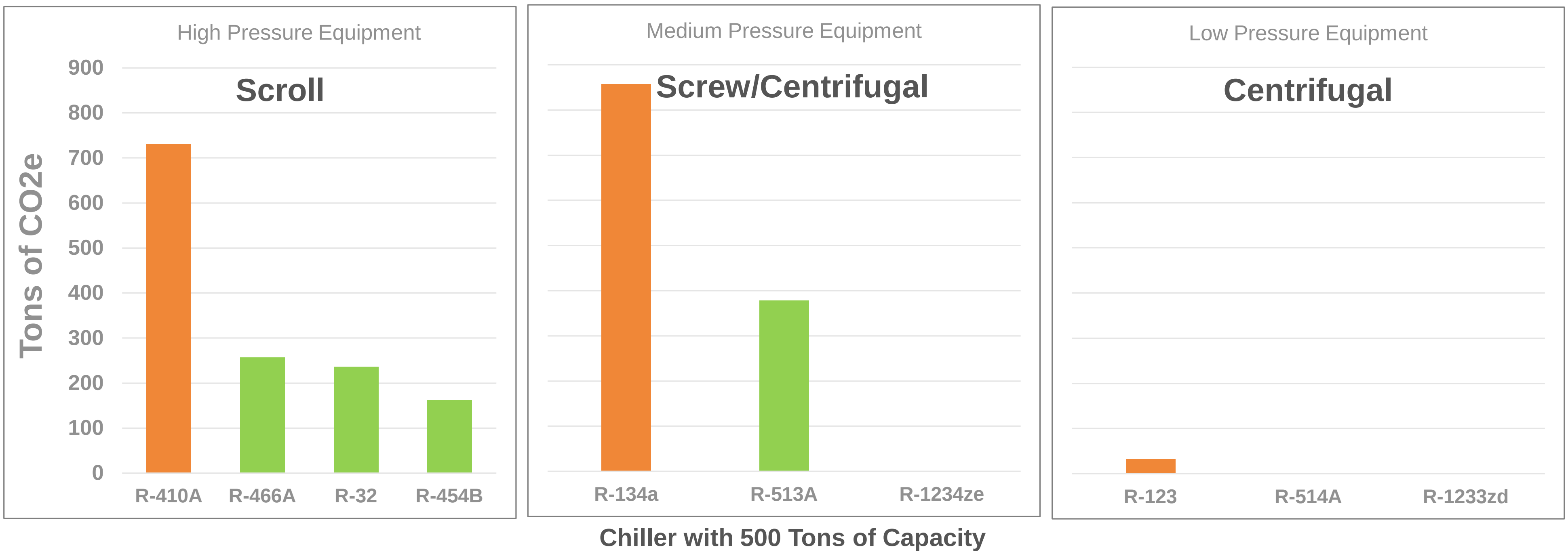
Refrigerant GWPs

Pressure	Refrigerant	GWP
High	R-454B	467
	R-32	675
	R-466A	733
	R-410A	2088
Medium	R-134a	1430
	R513A	630
	R1234ze	4
Low	R-123	77
	R-514A	1.7
	R-1233zd	1

Step 2: Consider Refrigerant Selection

Lower GWP = Lower possible CO_2 emissions



Keep refrigerant in the unit!

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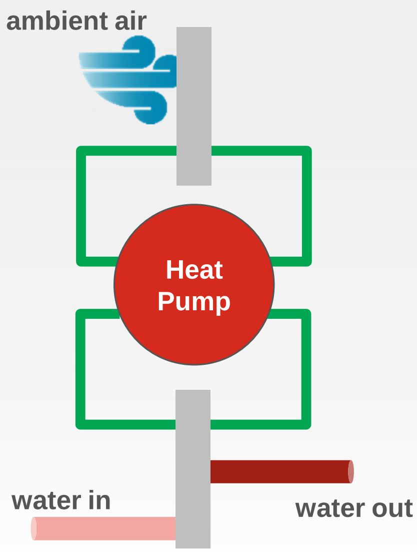
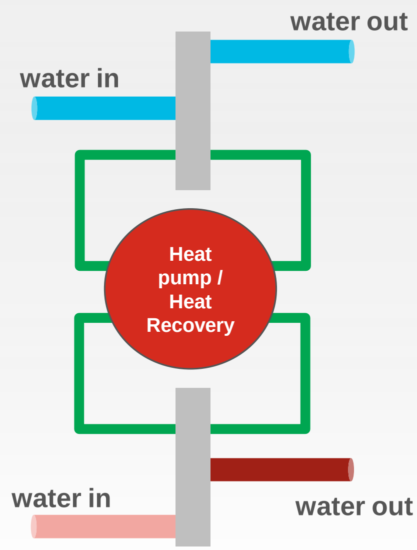
Hot Fluid Providers

Air-to-Water



Examples:
- *Air-to-Water Heat Pump (AWHP)*
- *Water-source heat pump (cooling mode)*

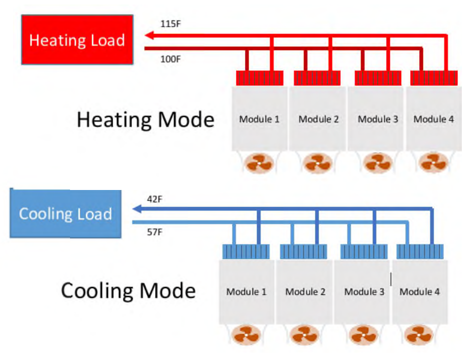
Water-to-Water



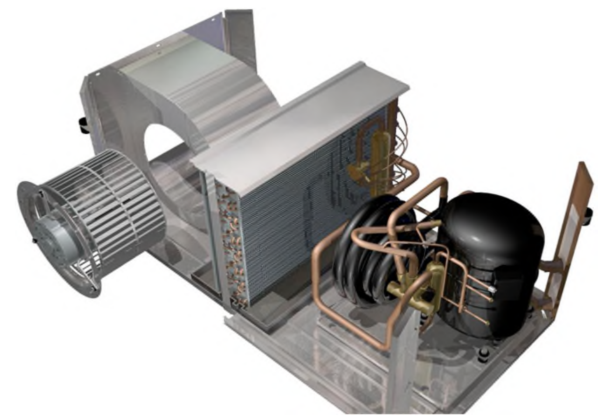
Examples:
- *Water-Source Chiller-Heater*
- *Heat recovery chiller*
- *Water-to-water heat pump*

Air-Water Heating

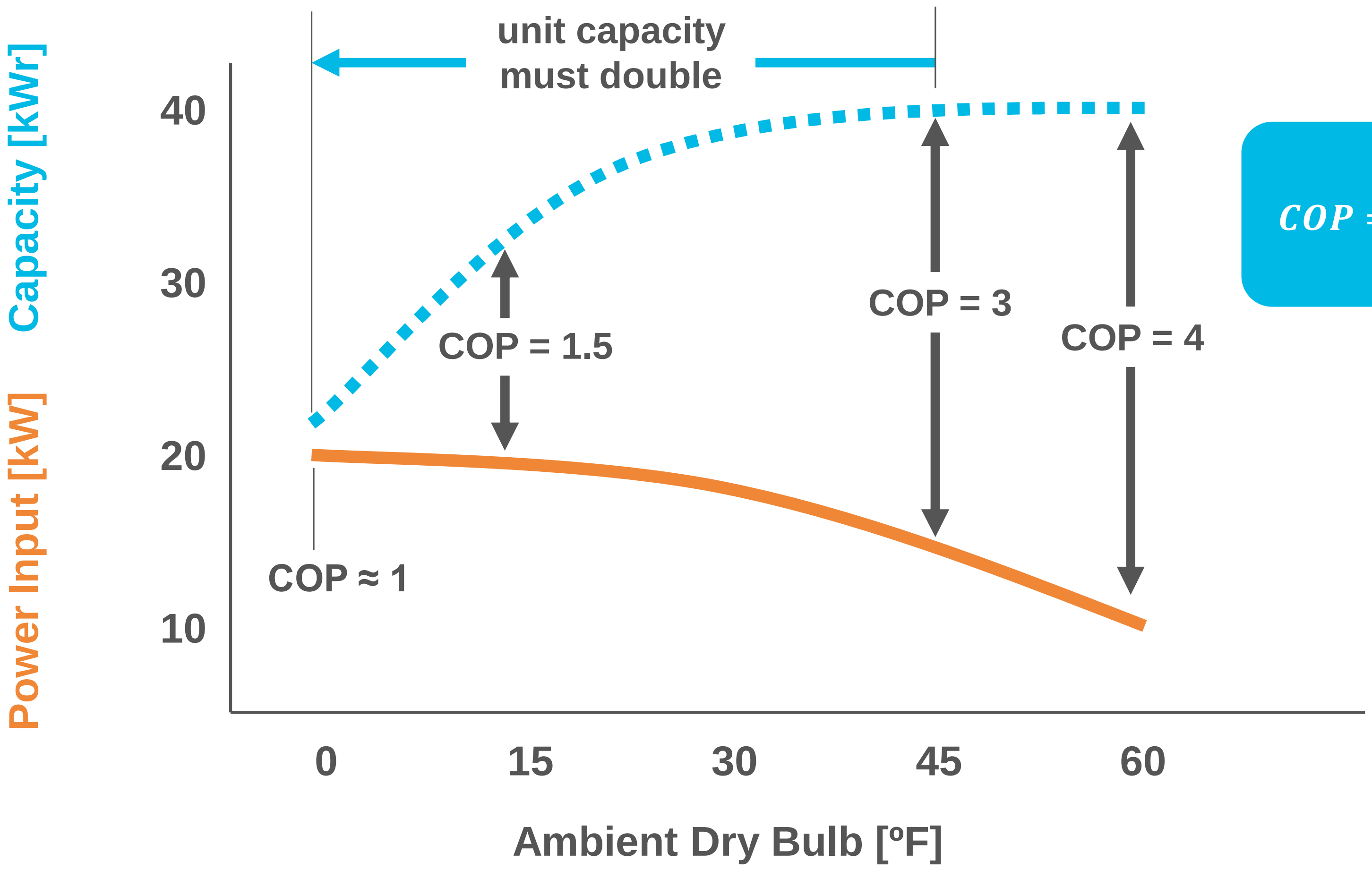
- Two-pipe changeover (either heating or cooling)



- Water-source heat pump (cooling mode)

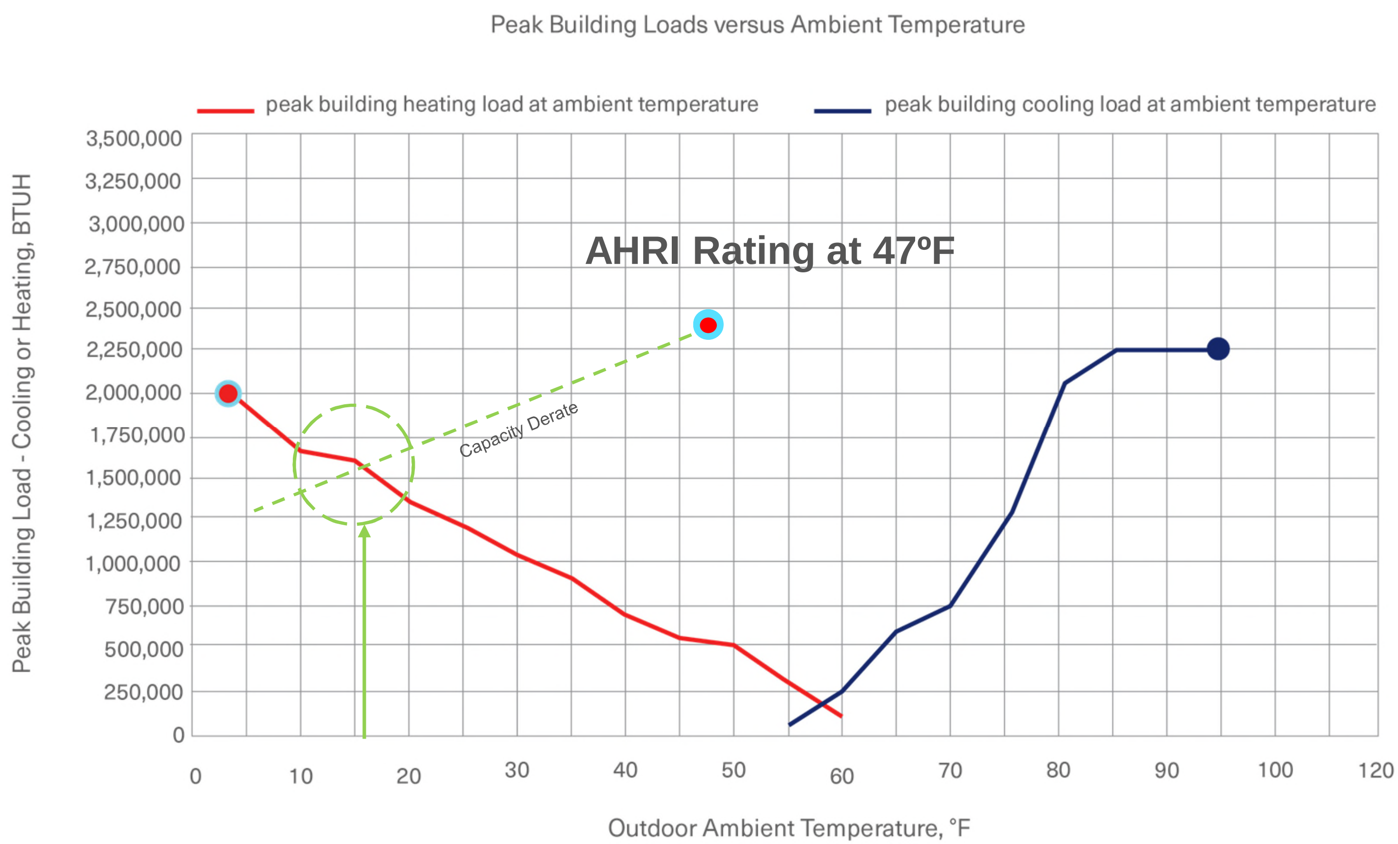


Air-Water Heat Pump Example



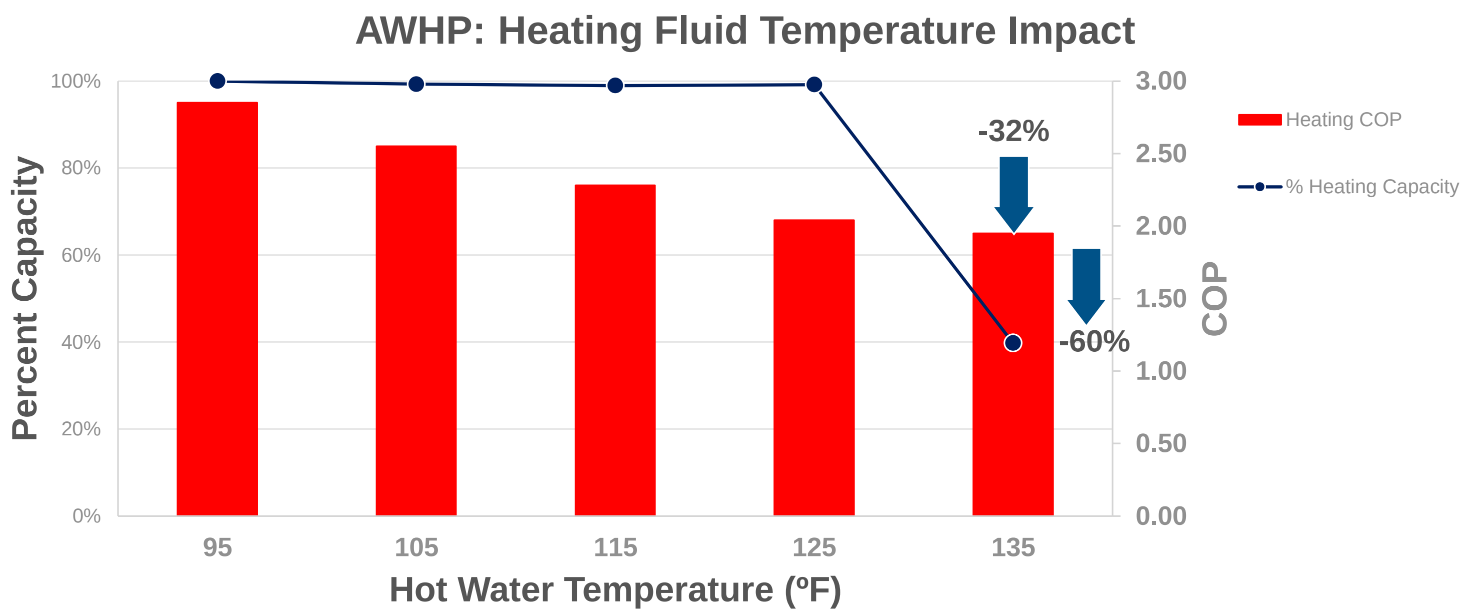
$$COP = \frac{Capacity\ Output\ [kW]}{Power\ Input\ [kW]}$$

Rerating the Heat Pump



Air-water Heat Pump (Scroll Compressors)

Heating Fluid Temperature Impact



Lesson: Select heating fluid temperature JUDICIOUSLY!

Water-source heat pumps are

Air-Water Heaters

We need to change our paradigm:

- When an airstream is cooled, the water stream is heated
- What water temperature is available?

Airstream heat sources:

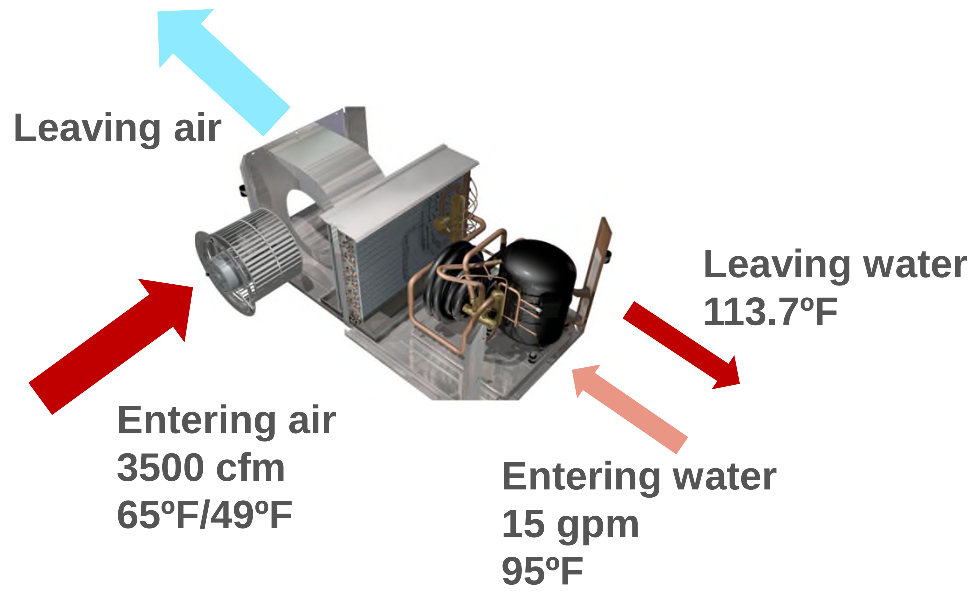
- Electronic areas (e.g. servers, switch gear)
- Exhaust air streams
  - 65ºF in winter
  - 73ºF in summer

Example: 10 Ton Nominal “WSHP” - Air-Water Heater

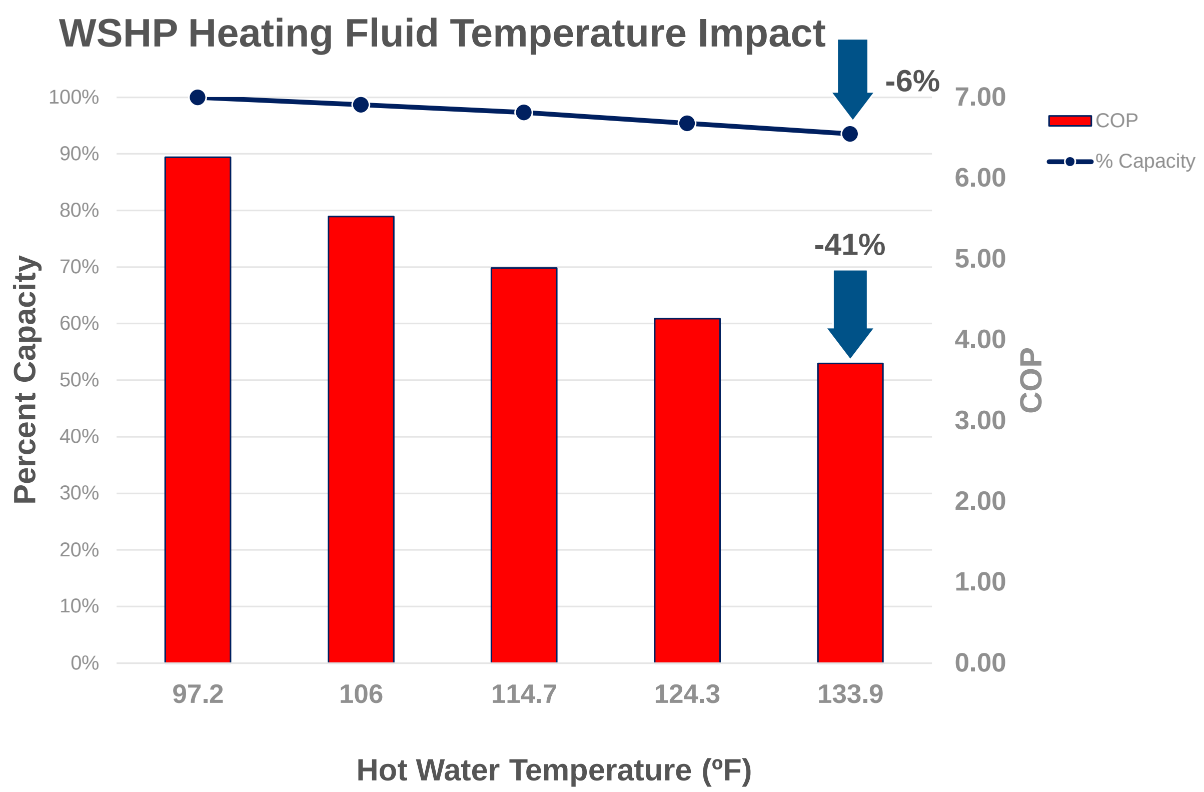
Examples use exhaust air stream

- Winter: 65ºF entering
- Summer: 73ºF entering

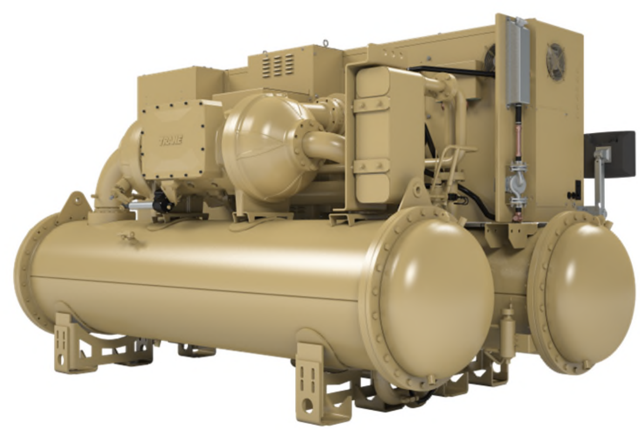
Heating fluid capacity: 140 MBh



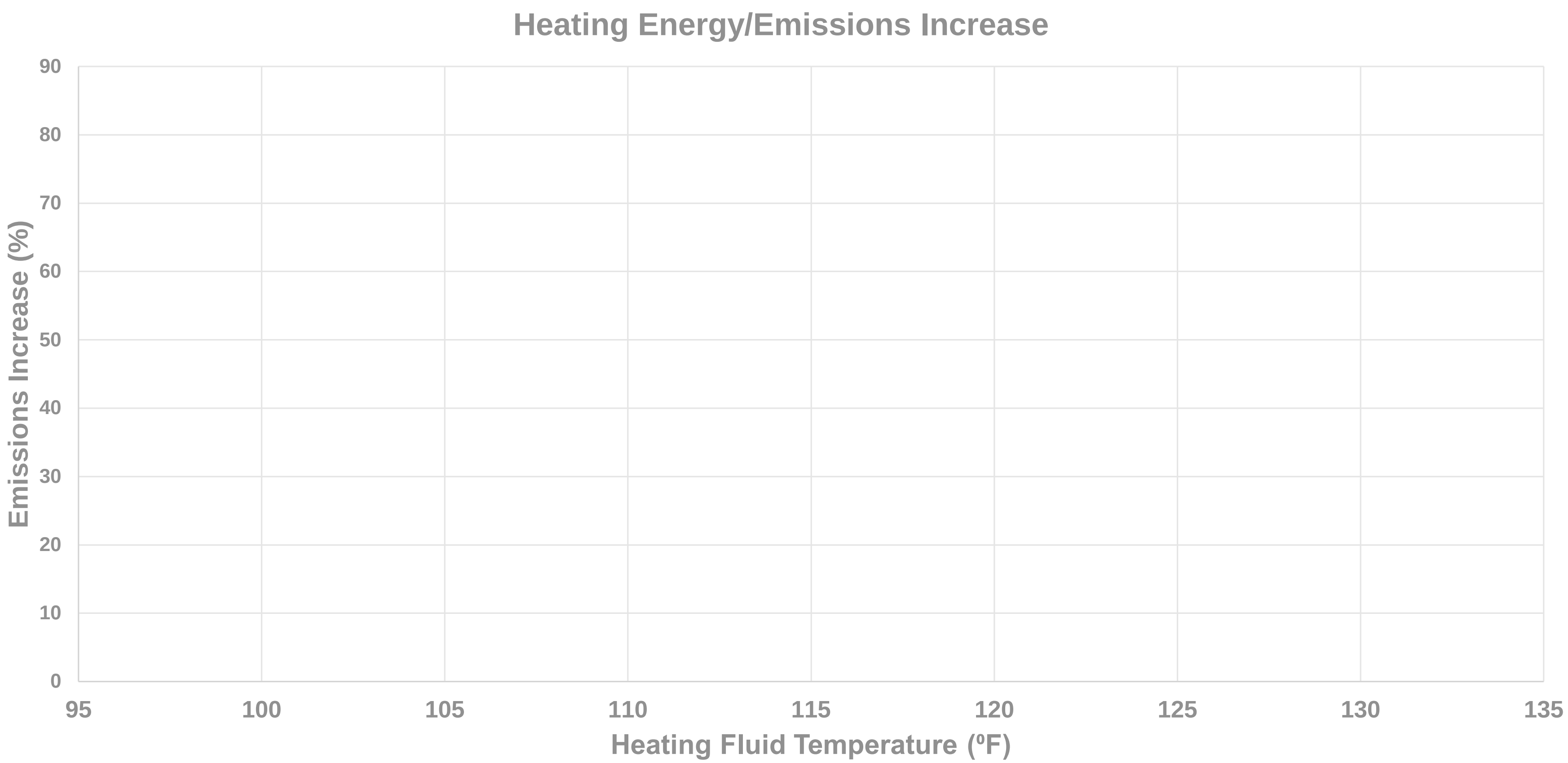
Heating Fluid Temperature Impact



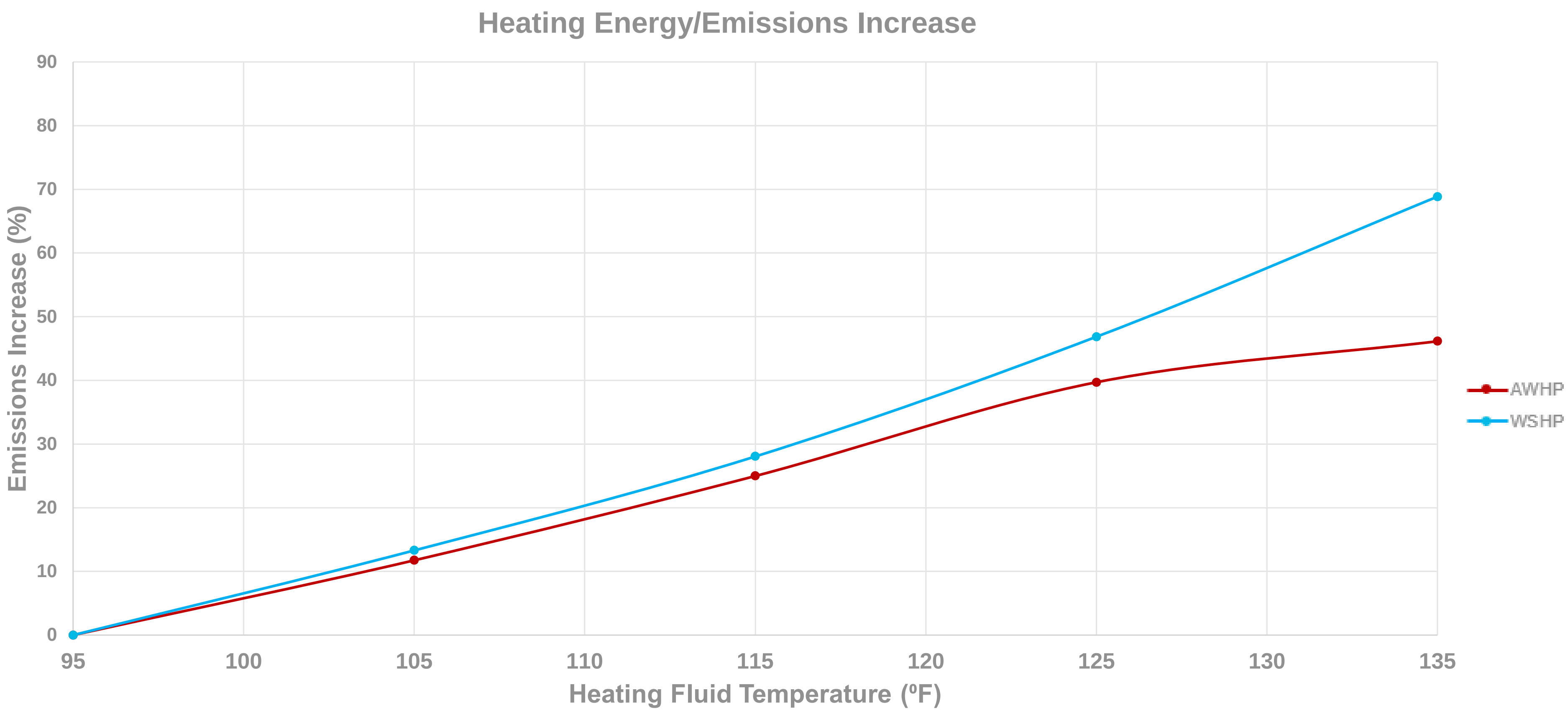
Water-to-Water Heating Units



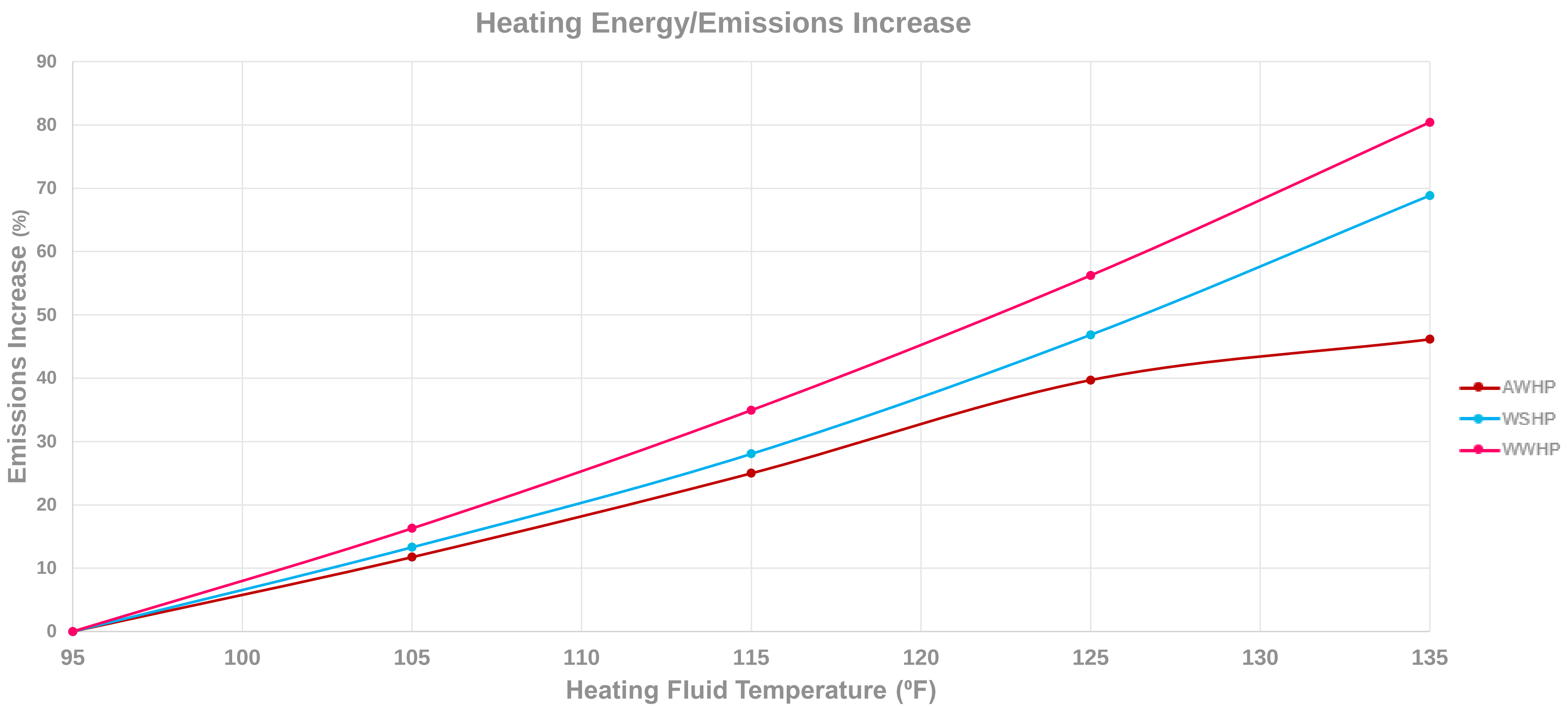
Proper Heating Fluid Design Temperature



Proper Heating Fluid Design Temperature



Proper Heating Fluid Design Temperature



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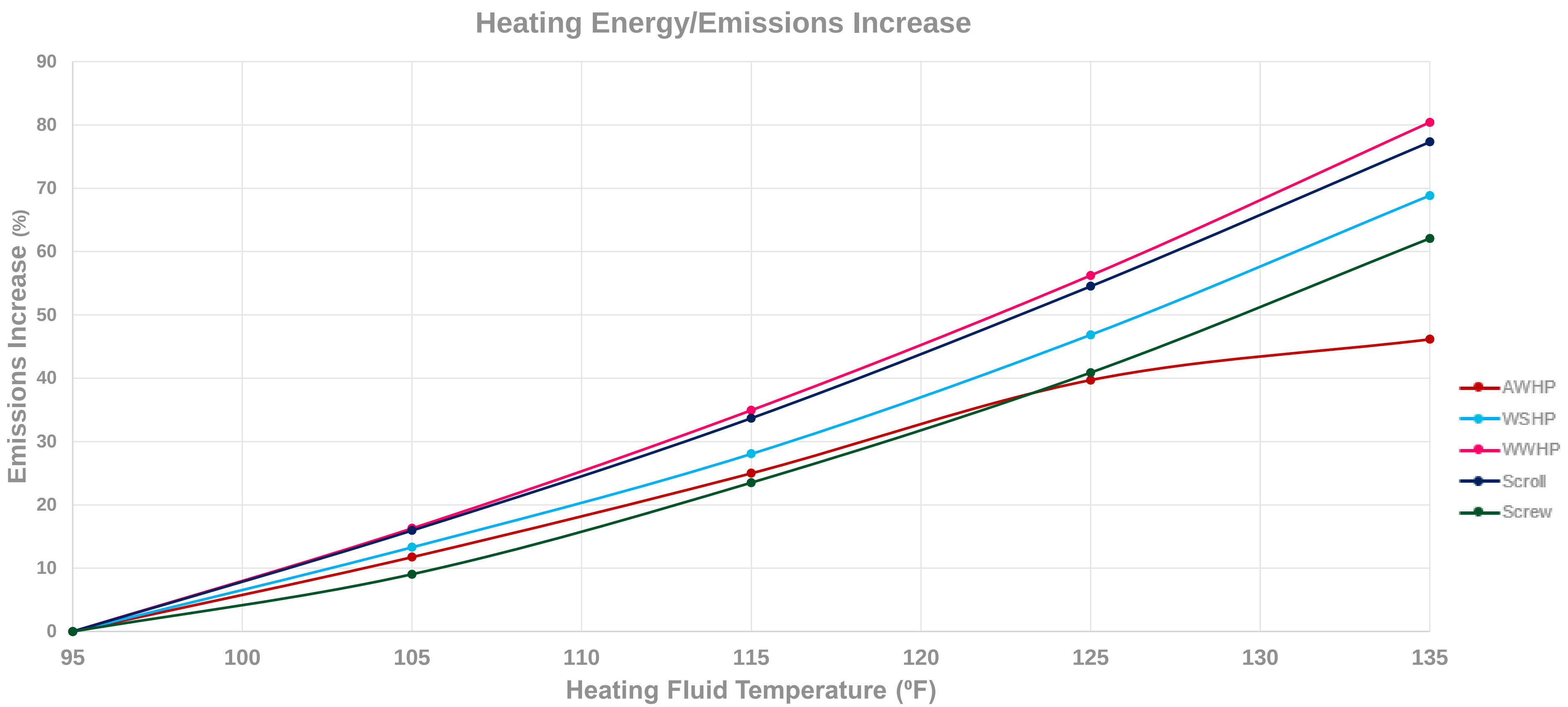

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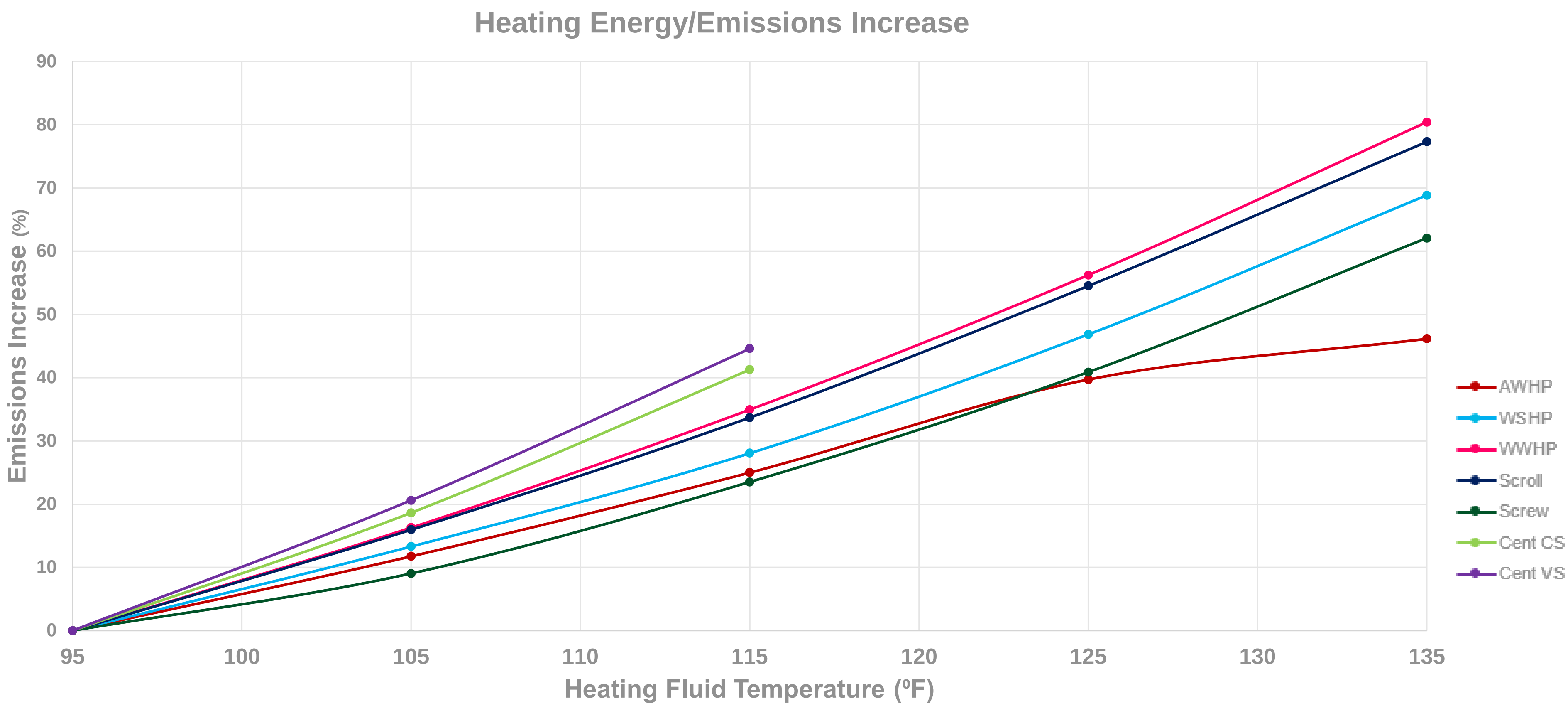
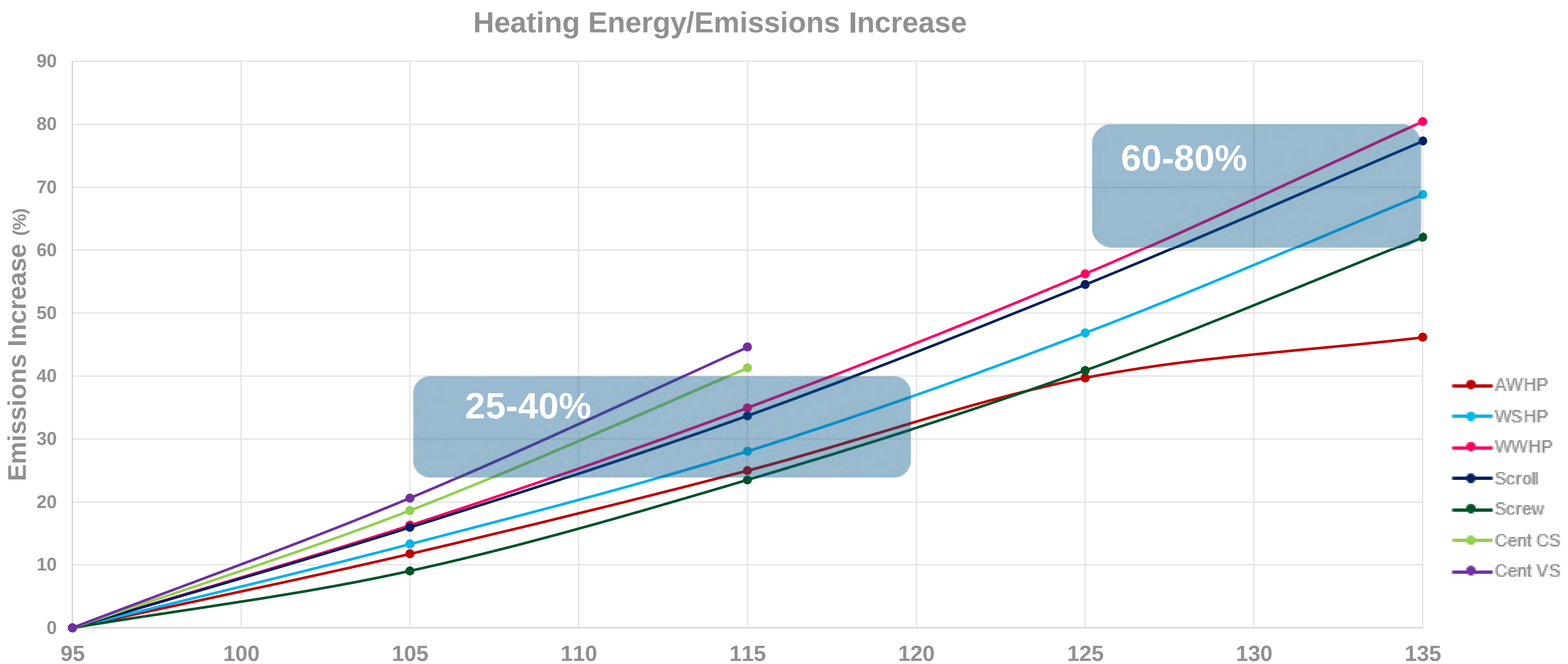


Proper Heating Fluid Design Temperature



Heating supply fluid temperature design guidance: 105ºF-120ºF (40ºC-50ºC)
Size heating units at design heating fluid temperature

Learning Objectives

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3. Recognize energy and capacity impacts of:
   - Heating water temperature
   - Heat source temperature
4. Appreciate differences from traditional chilled water system design
   - Equipment sizing and unloading
   - Flow rates
   - Redundancy
   - Heat availability
     - System configuration / piping
     - System controls
   - Reliability / Simplicity

Unit Selection Guidance

Unit selection

- Dependent on design intent
  - Heat recovery: Base on simultaneous heating and cooling loads
- Heating fluid temperature: 105-120ºF (40-50ºC)
- Heat source temperature

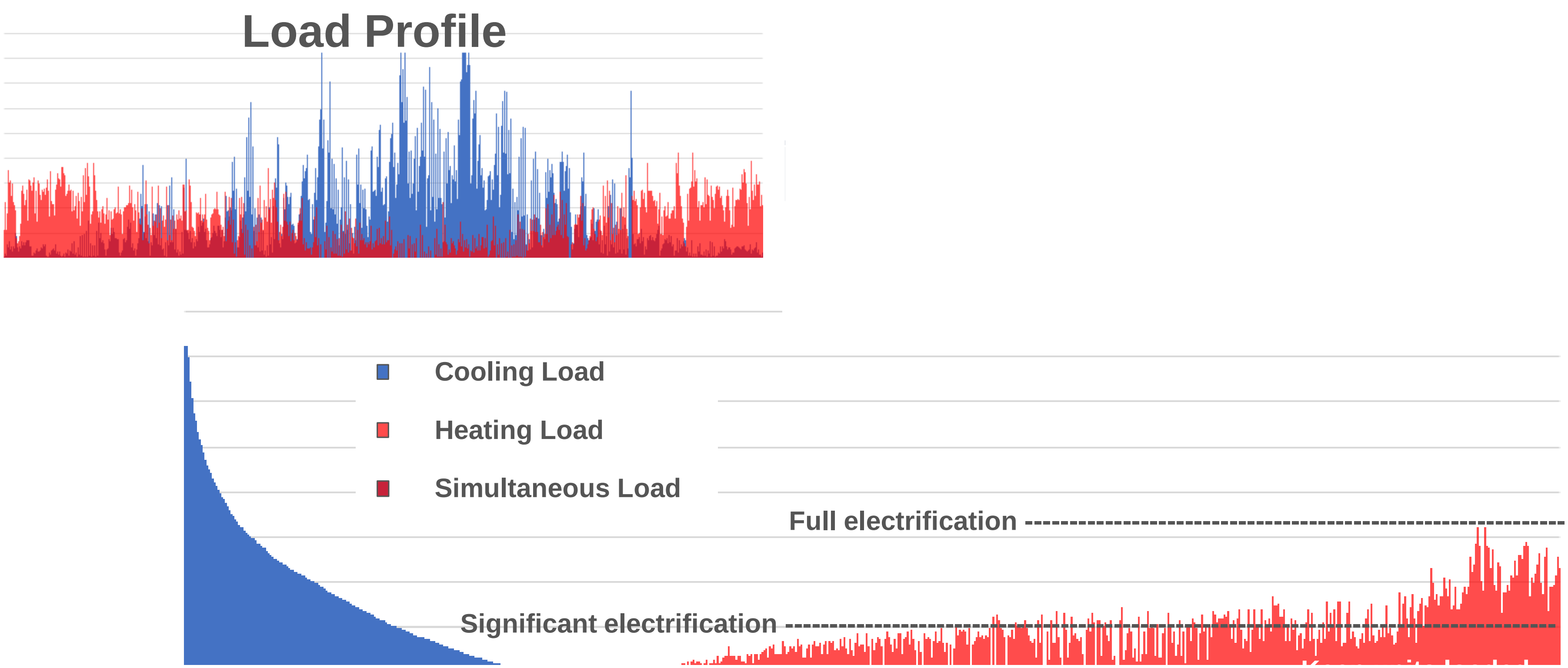
Unloading

- Ensure unit operates efficiently
- Load centrifugal units per manufacturer's requirement

Defrost

- Consider multiple units for redundancy/ reliability

Unit Sizing – Know Your System Loads



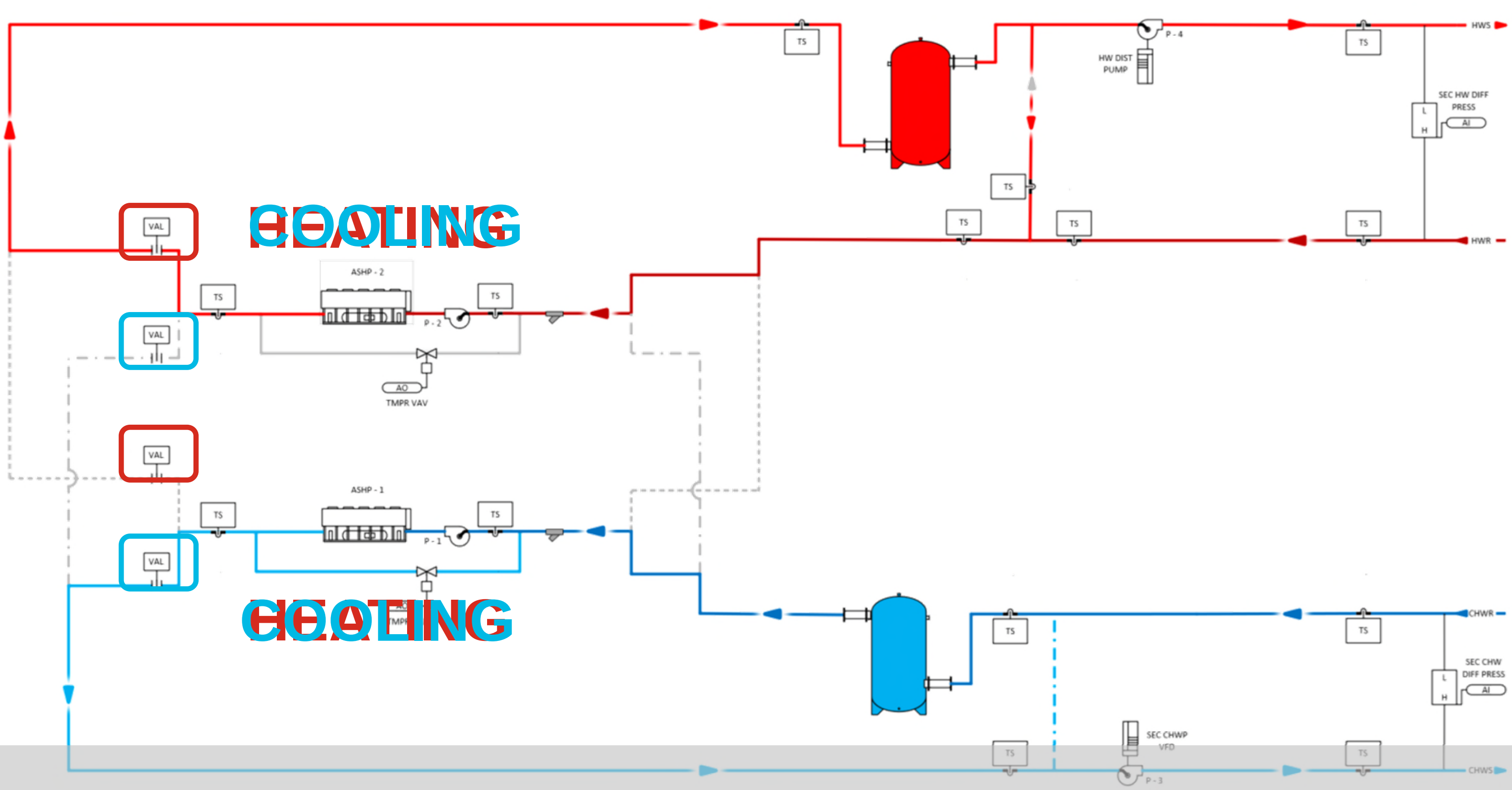
Lesson: Know the loads

Flow Rate Limitations

- Some heat pumps designed for cooling, and being applied for heating
- Minimum flow rate limits maximum heating ΔT
  - Maximum heating ΔT may be limited (15-20ºF)
- Impacts
  - Selected heating flow rate is often near minimum
  - Flow must remain constant
  - Highly consider primary-secondary system configuration

Four-pipe distribution

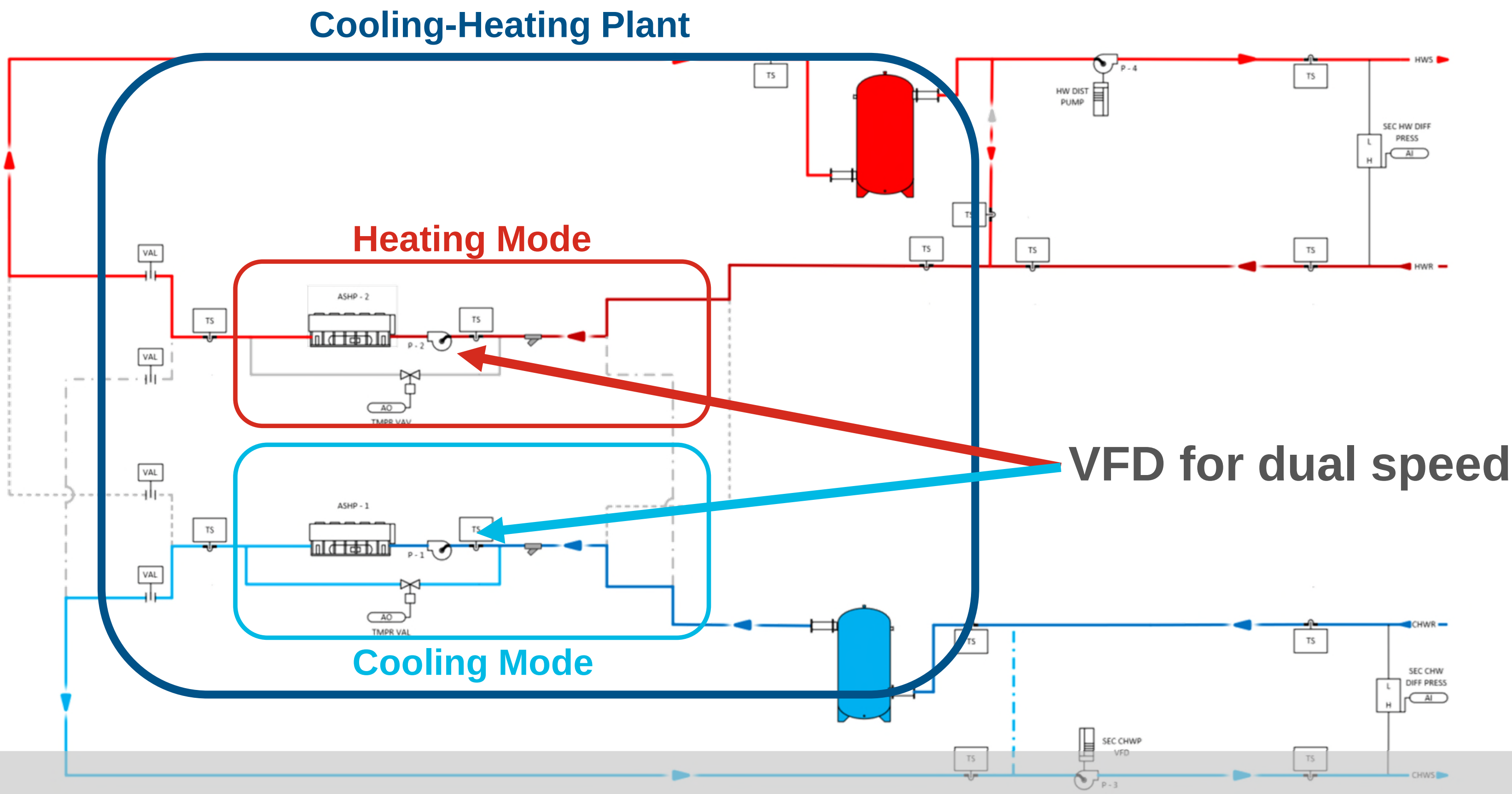
Primary-Secondary



Lesson: Keep it simple with primary-secondary

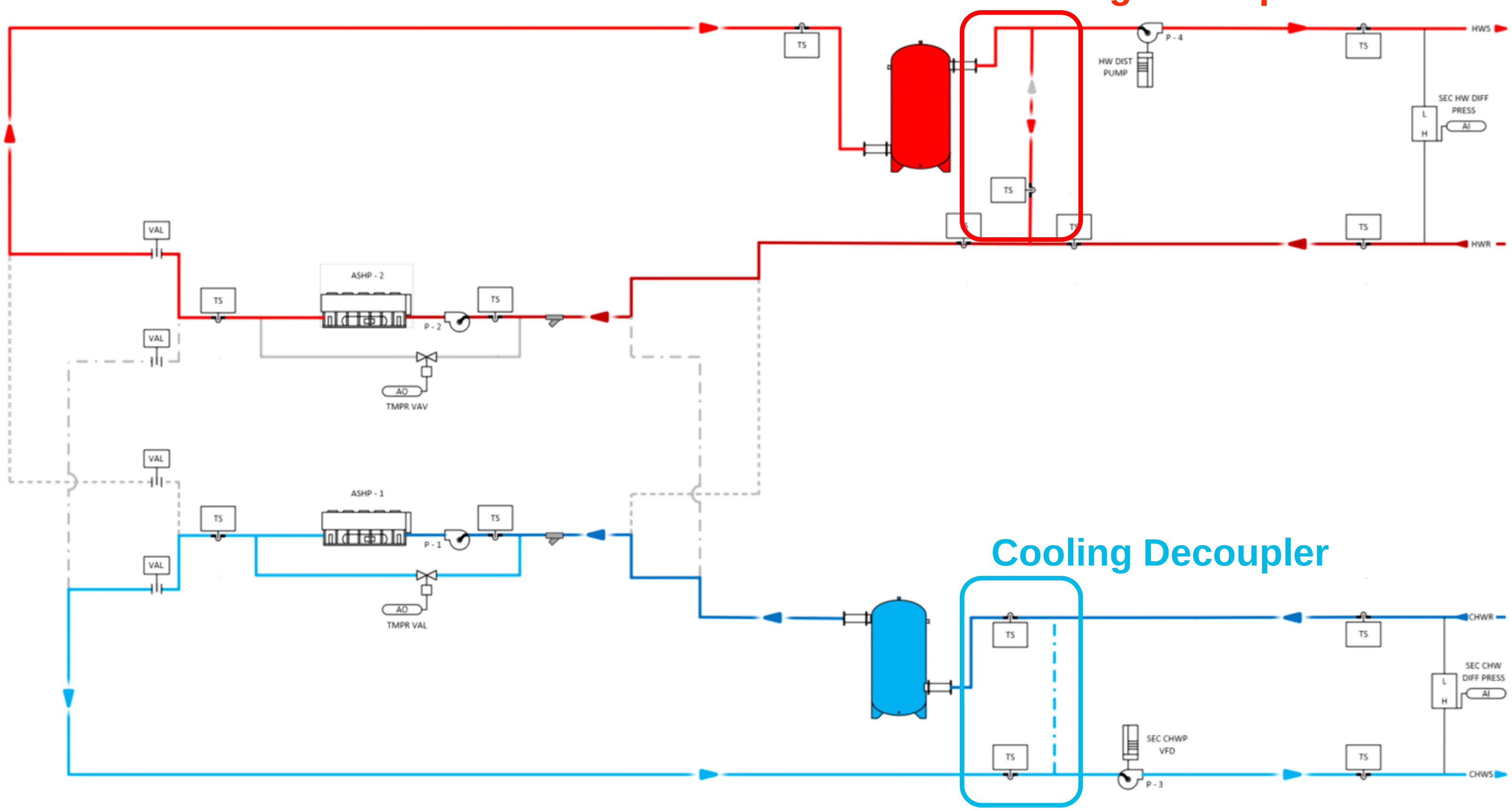
Primary-secondary

Plant Arrangement



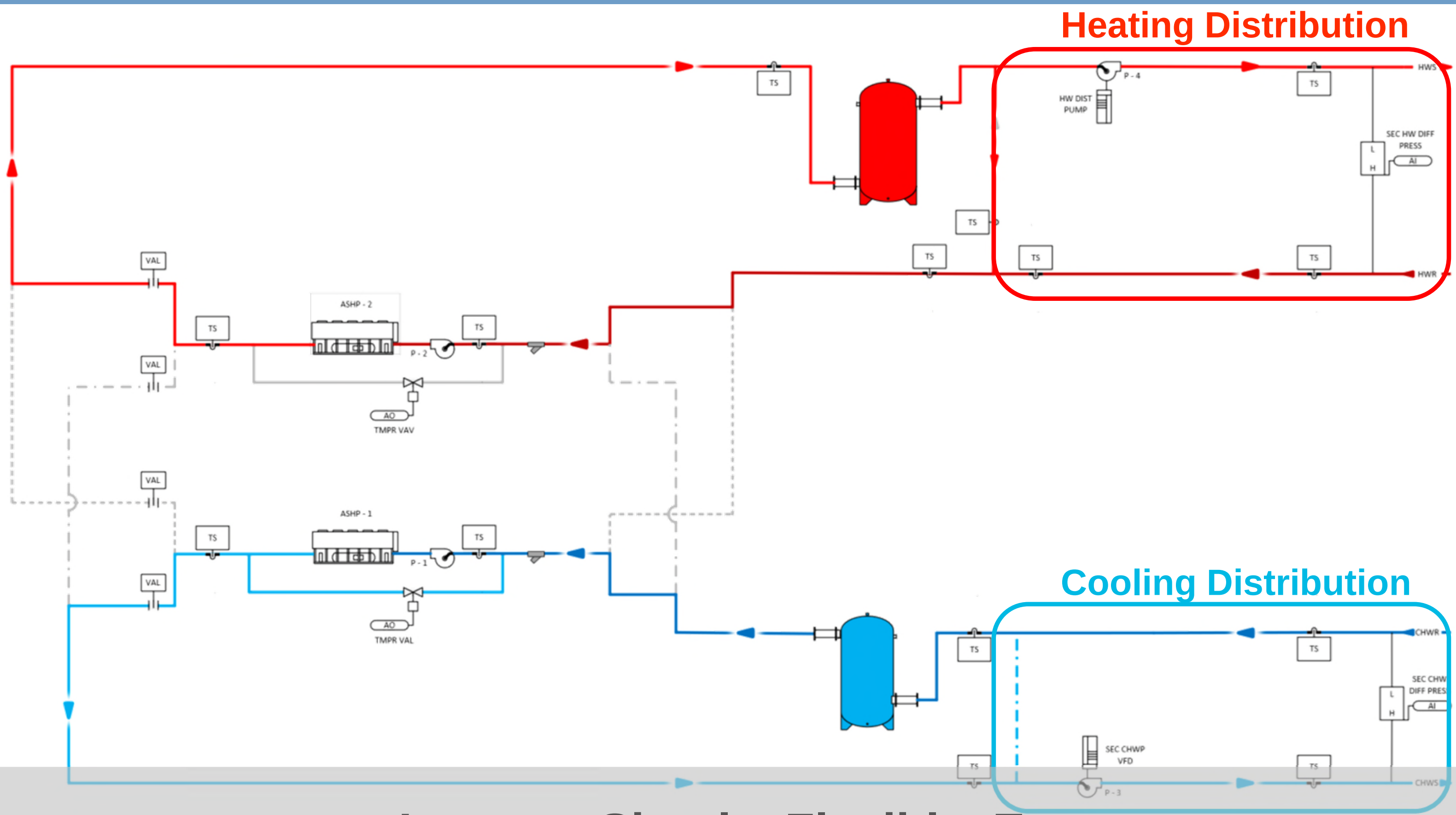
Lesson: Flexibility

Primary-secondary
Decoupler



Primary-secondary

Distribution



Lesson: Simple, Flexible, Easy

AWHP Consideration: Mitigating Defrost

Aspect	Impact	Comments
Oversize units	Increased cost and size	Consider unloading capabilities
Increase number of circuits	Increased cost and size	Packaged units with multiple circuits have only one defrost at a time
Timing	Controls coordination	Consider for cooling and heating plant controls
Backup	Increased cost and space	Electric boiler (low COP) Other fuel

Unit Placement Matters

Heat Recovery

Chilled-water system configuration options

Loading Units

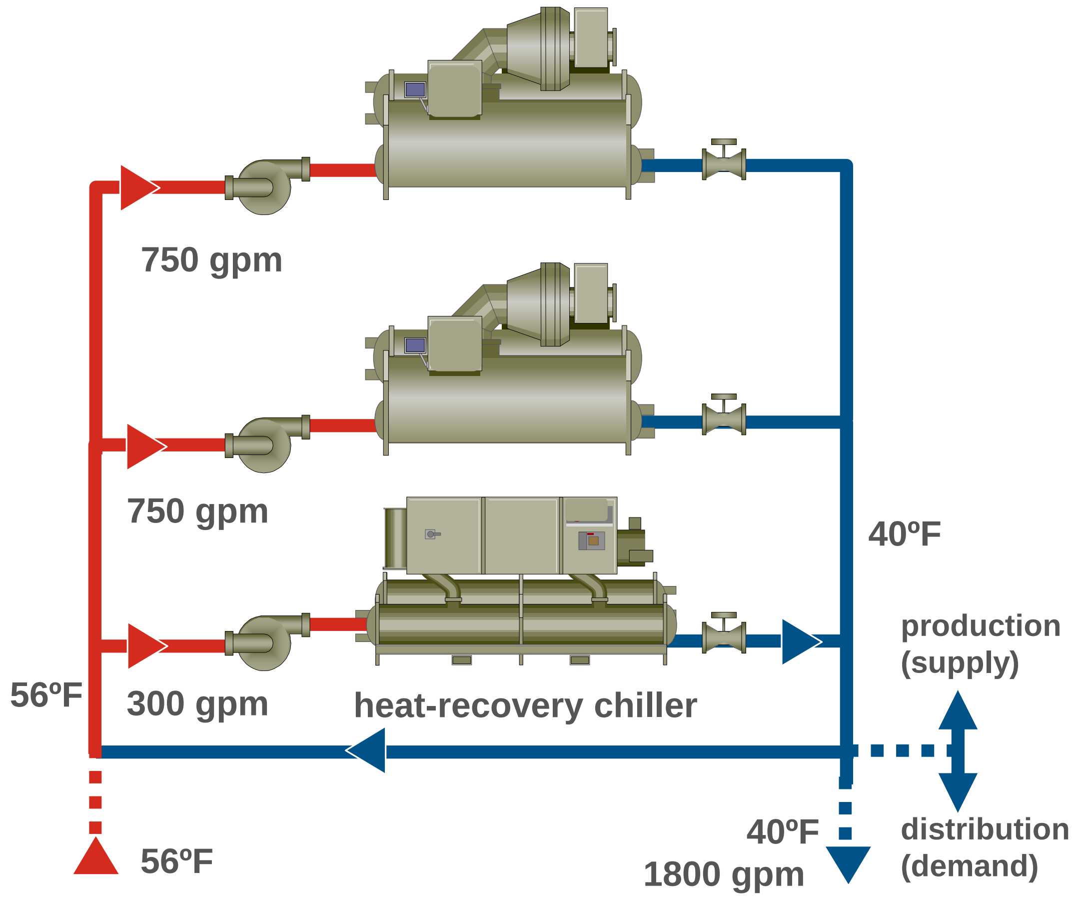
Design

- Two 500-ton cooling only chillers
- One 200-ton heat recovery unit
  - 3000 Mbh heating design
- 16ºF ΔT

Operating point

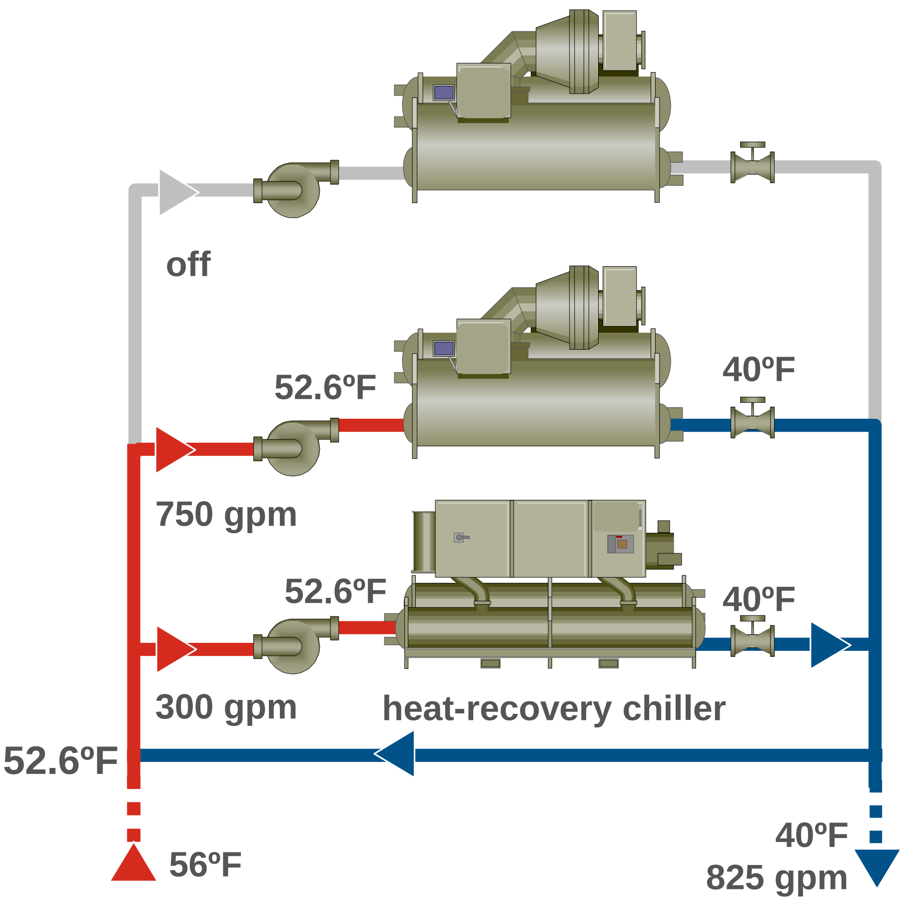
- System cooling load: 550 tons
- Heating load: 2600 MBh
- Heat available = Cooling load + heat of compression
- Using a Coefficient of Performance (COP) of 4
  - ~ 8,250 MBh heat available
  - 175 tons of cooling can supply ~ 2,625 MBh

Design: Primary-Secondary



Sub-optimal configuration – parallel evaporators

Unit Loading



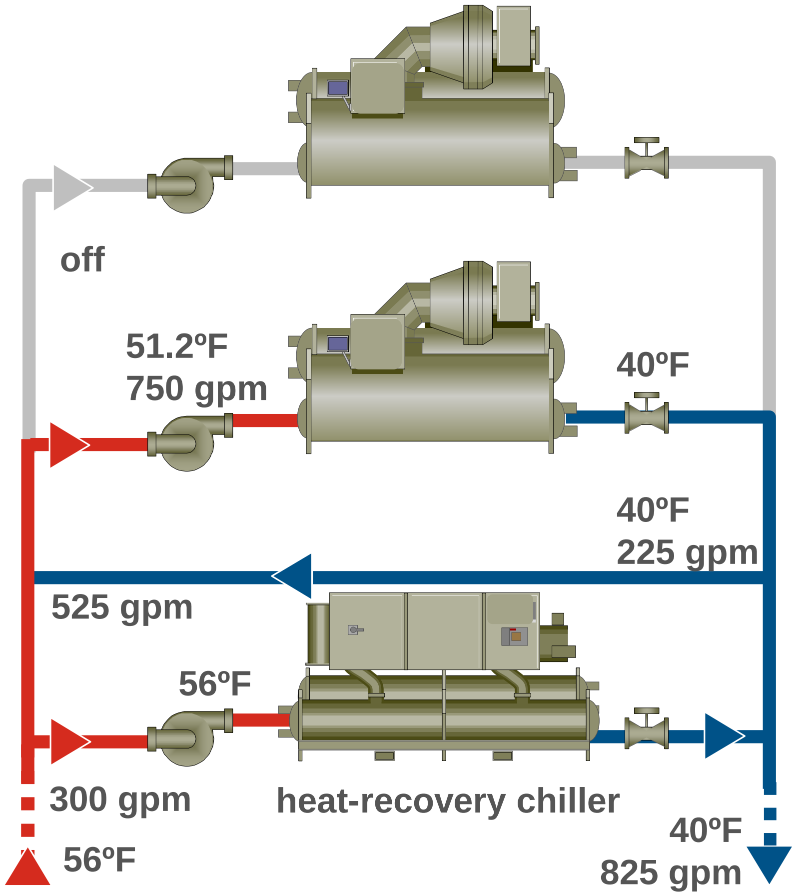
All operating units loaded to equal percentages

	Cooling (tons)	Heating (MBh)
Building loads	550	2,600

Not Optimal

Primary-secondary – preferential configuration

Loading Units

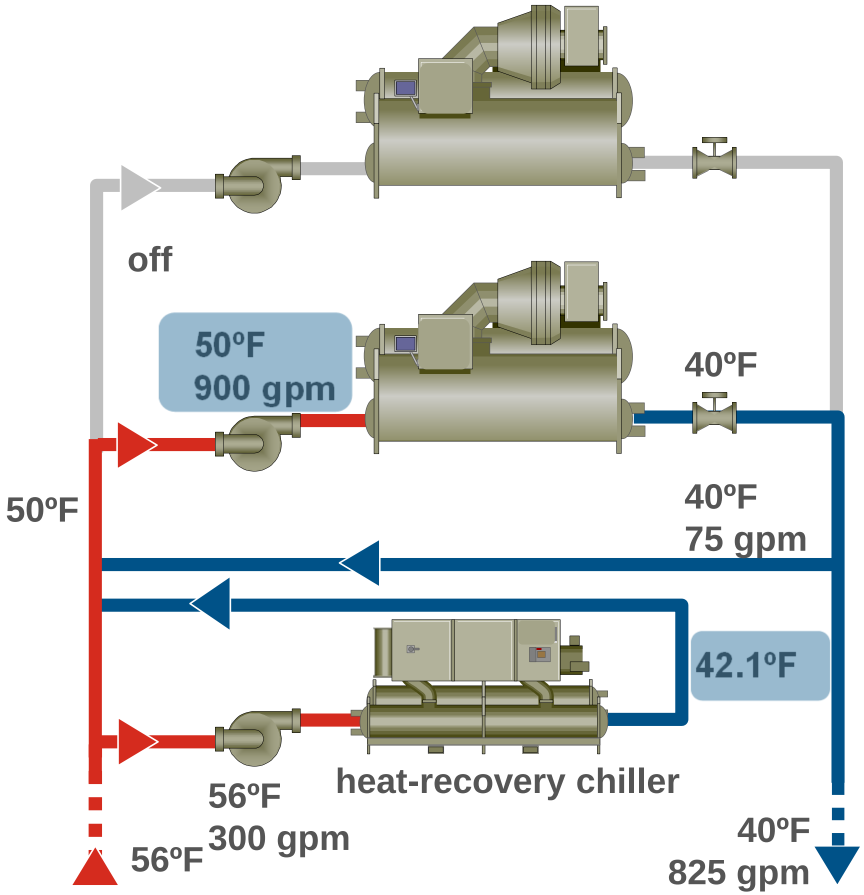


Units on load side of bypass loaded preferentially

	Cooling (tons)	Heating (MBh)
Building loads	550	2,600
Heat recovery chiller	200	3,000
Cooling chiller	350	0
Heat purchased		0

Sidestream configuration (primary-secondary)

Loading Units

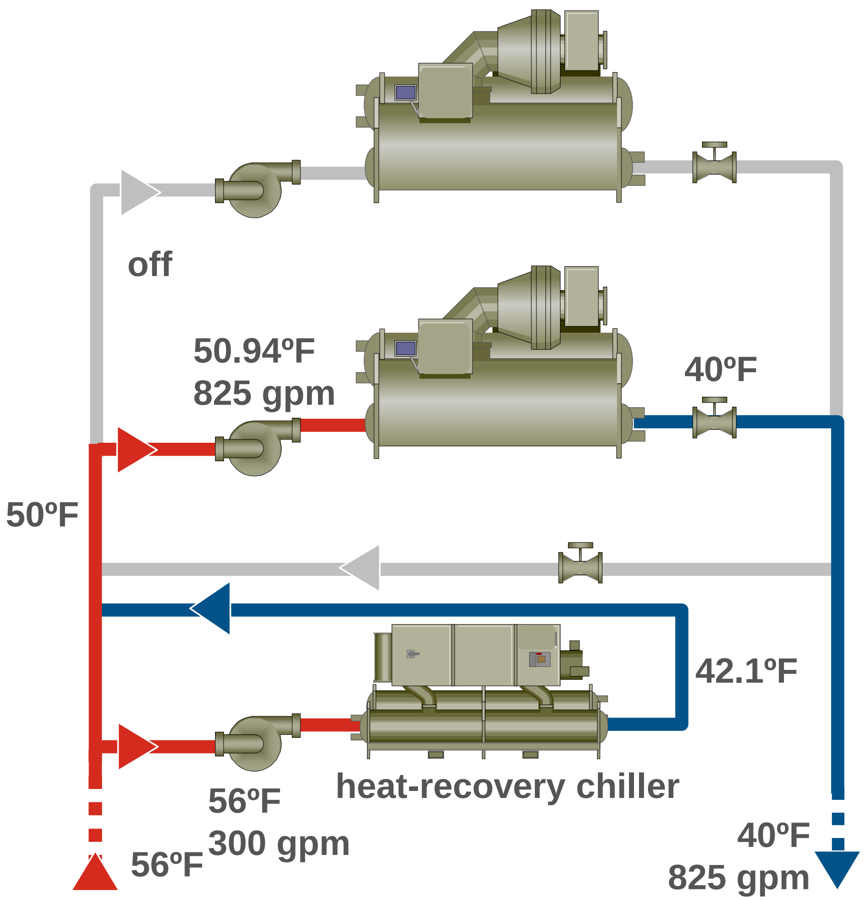


Heat recovery chiller loaded to exactly satisfy heating load and temperature

	Cooling (tons)	Heating (MBh)
Building Loads	550	2,600
Heat recovery chiller	174	2,600
Cooling chiller	376	0
Heat purchased		0
Heat that must be rejected from the heat recovery chiller		0

Sidestream configuration (Variable Primary Flow)

Loading Units



Unit loaded to exactly to satisfy heating load

	Cooling (tons)	Heating (MBh)
Building loads	550	2,600
Heat recovery chiller	174	2,600
Cooling chiller	376	0
Heat purchased		0
Heat that must be rejected from the heat recovery chiller		0

Simple and Reliable

System Design Examples

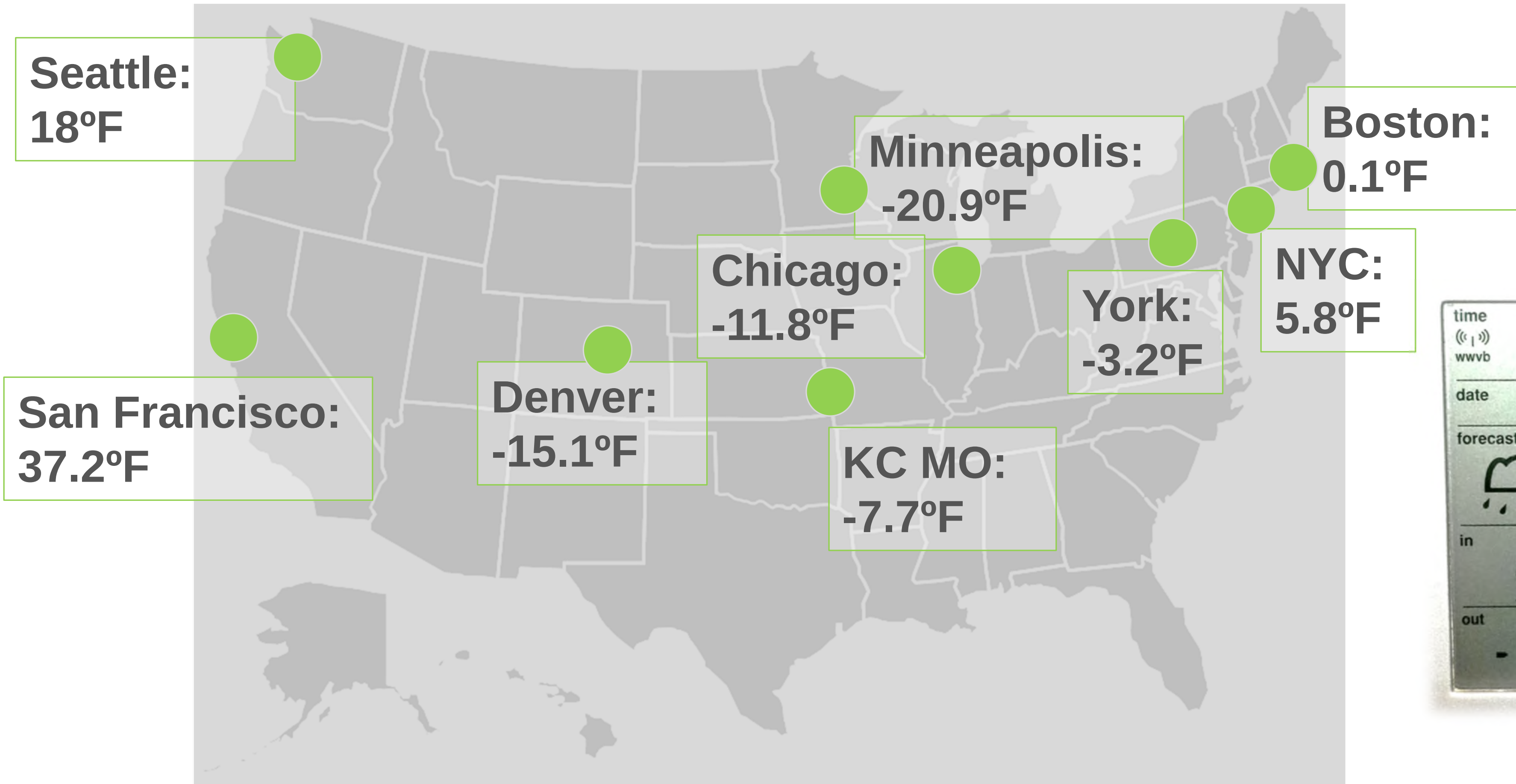
Using data for PNNL analysis for ASHRAE® 90.1-2019 determination

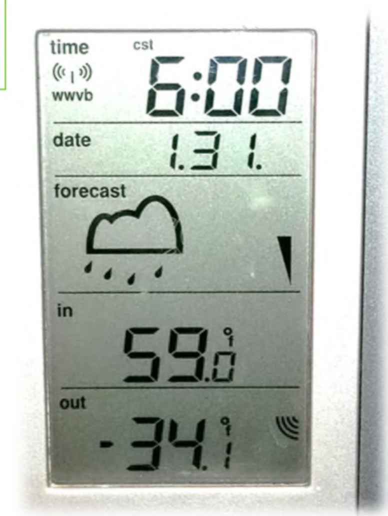
Example design

Secondary School: Climate Zone 5A

- Cooling: 263 tons (3,156 MBH)
- Heating: 2,448 MBh
  - 99.6% HDD: -2ºF
  - 20-year extreme temperature: -21ºF
  - 50-year extreme temperature: -26º F
  - HW supply Temperature 115º F
- Design parameters
  - N+1 heating redundancy
  - 67% cooling redundancy
  - Changeover system

Air-Source Heat Pumps in Cold Climates – U.S. 5 Year Extreme Temperatures





Air-Source Heat Pumps in Cold Climates – Canada: 5 Year Extreme Temperatures

City	Province	5-Year Extreme (ºC)
Vancouver	British Columbia	-10.0
Calgary	Alberta	-34.3
Regina	Saskatchewan	-38.9
Saskatoon	Saskatchewan	-40.0
Winnipeg	Manitoba	-37.8
Ottawa	Ontario	-29.1
Toronto	Ontario	-22.6
Halifax	Nova Scotia	-19.3

Cold Climate Challenges*

- *“Air-source heat pumps have limitations for heating in very cold climates. More research is needed to advance heat pump technologies…”*
- *“Using fossil-fuel boilers and furnaces as backups may need to be considered…”*
- *“There are electric grid infrastructure challenges in achieving building decarbonization goals.”*
- *“Supplementing energy efficiency with demand flexibility and storage strategies can reduce the grid impact.”*
- *“Increasing stringency and enforcement of energy codes are critical for decarbonization.”*

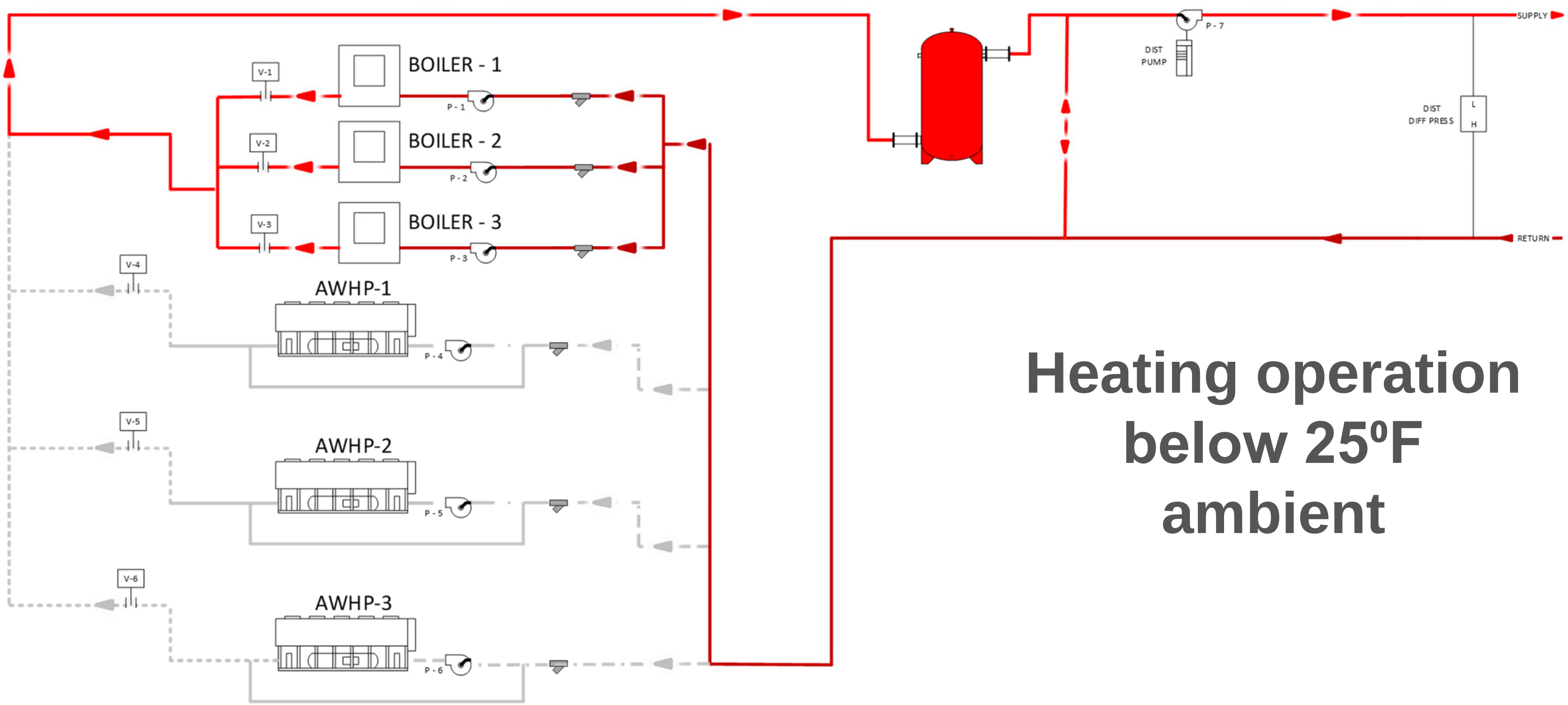
***ASHRAE Position Document on Building Decarbonization (2022)**
ASHRAE Position Document on Building Decarbonization.fm

System 1

Cold Climate Electrification with Backup Heating

Unit	Number of units	Cooling Available (tons)	Heating at 25ºF (MBh)	Heating at -21ºF (MBh)	Comment
AWHP	3	492	4800	0	Oversized for heating
Boilers	3		Not required	3,672	For operation below 25ºF

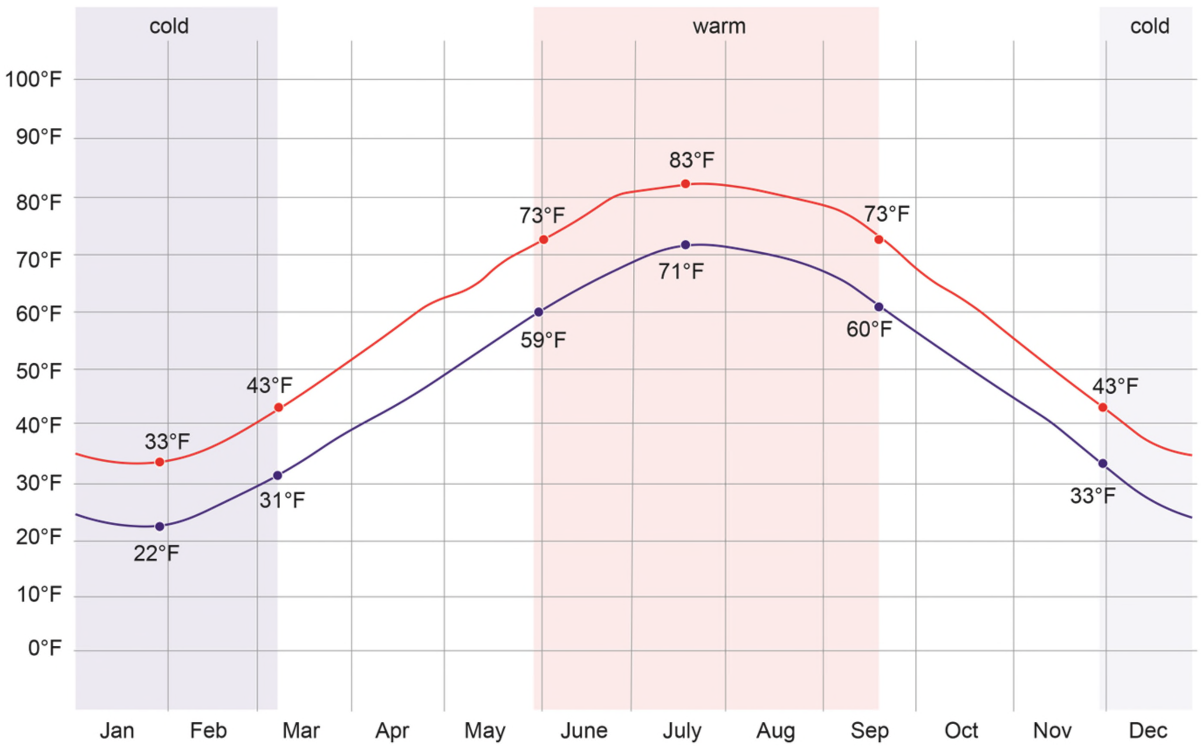
System 1
Cold Climate Electrification with Backup Heating



Heating operation below 25⁰F ambient

System 1
Cold Climate Electrification with Backup Heating

Average high and low temperatures in Chicago



Back-up heat is not needed for many hours.

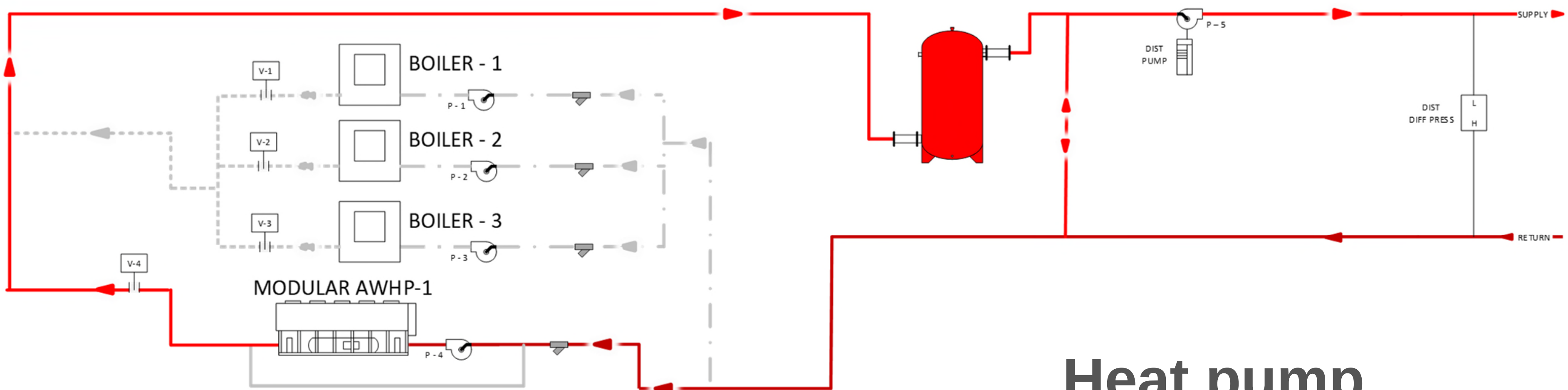
Significant electrification is available even with fossil-fueled backup.

System 2

Cold Climate Electrification with Backup Heating

Unit	Number of units	Cooling Available (tons)	Heating at 0ºF (MBh)	Heating at -21ºF (MBh)	Comment
Modular AWHP	1	290	2100	0	10 modules (N+1)
Boilers	3		As needed	3,672	For operation below 0ºF

System 2
Cold Climate Electrification with Backup Heating



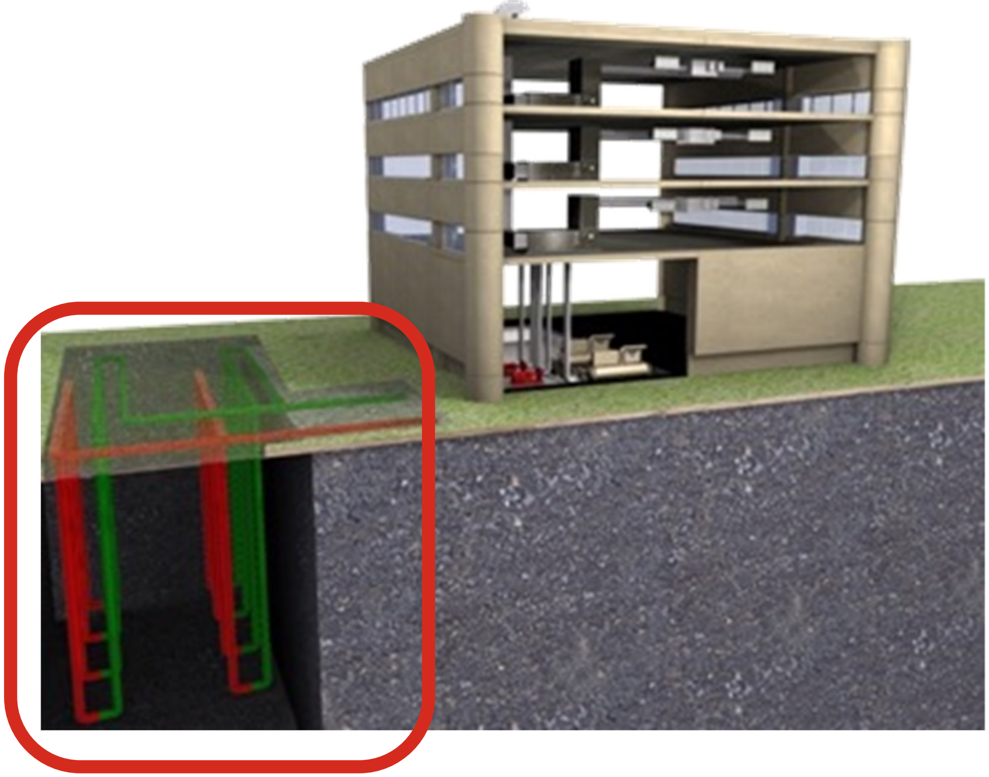
Heat pump operation down to 0ºF ambient

Large Building — Geothermal

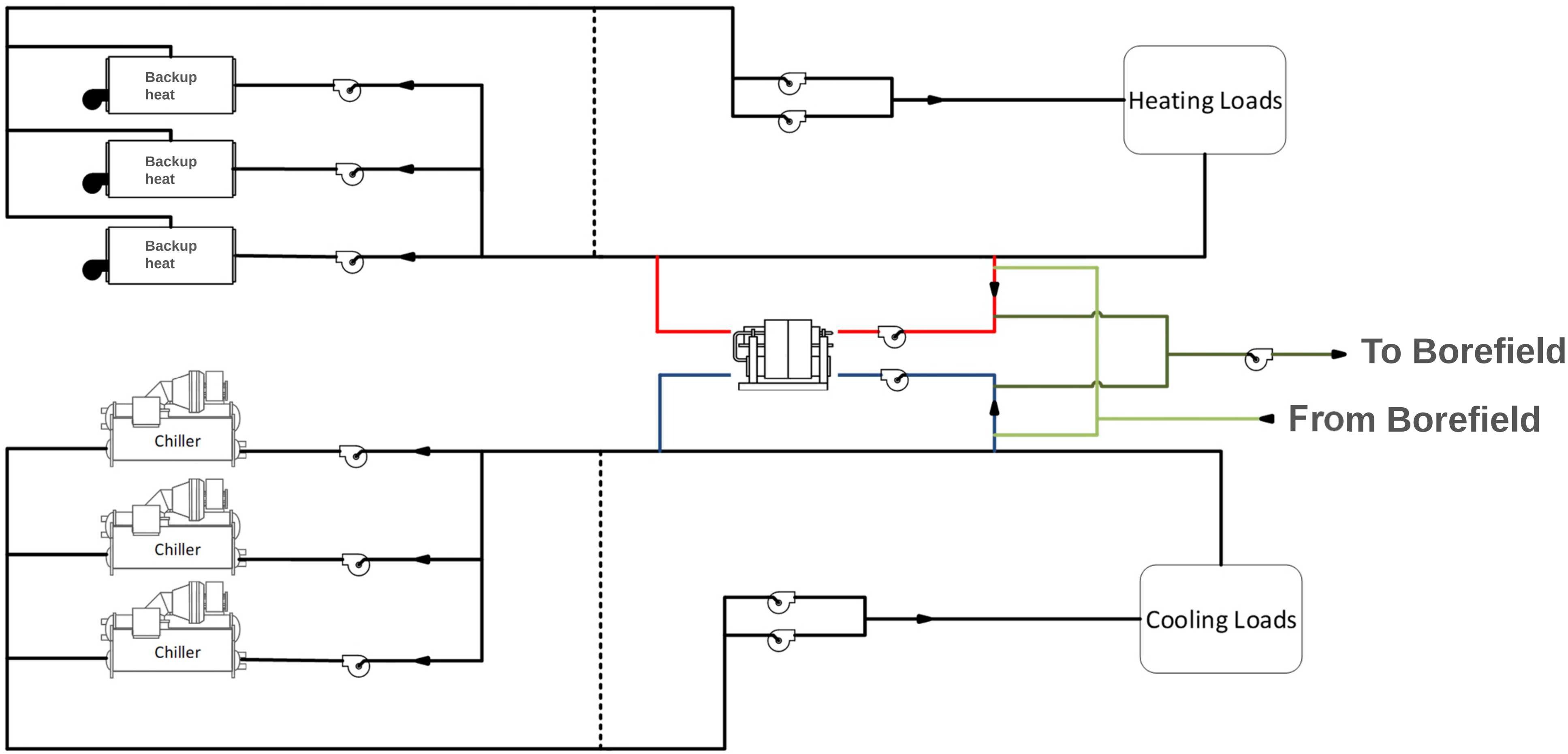
Geothermal

- Advantages
  - High efficiency
  - All electric
- Disadvantages of borefield
  - Space
  - Cost

$$$



Electrification — Geothermal



Financial Impact

Incentives

Fuel Switching Incentives

- Ex. New York Clean Heat Program
- $200/mm BTU offset

Fees

Carbon Cap

- Ex. New York City Local Law 97
- $268/metric Ton CO2e

Carbon Tax

- Ex. Canada
- $20-$50 / metric Ton CO2e

Carbon Price

Shadow Price

- $10-$50/metric Ton CO2e

General Guidance

- Define the intent
- Understand the limits and effects
  - Heat source
  - Heating fluid temperature: 105ºF -120ºF (40ºC -50ºC)
- Keep it simple
  - Primary-Secondary
  - Sidestream heat recovery
  - Develop "control sequence descriptions..." (sequence of operation)
  - Keep operators in mind

[ASHRAE Position Document on Building Decarbonization.fm]

Please fill out the DL Evaluation Form

Thanks for all the volunteering you do.
Let's all continue to "*Feed the Roots*."

Building Decarbonization (Electrification) for Hydronic Systems